## NASA/TM-2000-209891, Vol. 6



# Technical Report Series on the Boreal Ecosystem-Atmosphere Study (BOREAS)

Forrest G. Hall and David E. Knapp, Editors

# Volume 6 BOREAS AFM-04 Twin Otter Aircraft Flux Data

J. I. MacPherson and R.L. Desjardins

National Aeronautics and Space Administration

**Goddard Space Flight Center** Greenbelt, Maryland 20771

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# **BOREAS AFM-04 Twin Otter Aircraft Flux Data**

J. Ian MacPherson, Flight Research Laboratory, National Research Council Raymond L. Desjardins, Centre for Land and Biological Resources Research, Agriculture Canada

National Aeronautics and Space Administration

**Goddard Space Flight Center** Greenbelt, Maryland 20771

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## **BOREAS AFM-4 Twin Otter Aircraft Flux Data**

J. Ian MacPherson, Raymond L. Desjardins

## Summary

The BOREAS AFM-4 team used the NRC Twin Otter aircraft in 1994 and 1996 to make measurements in the boundary layer of the fluxes of sensible and latent heat, momentum, ozone, methane, and carbon dioxide, plus supporting meteorological parameters such as temperature, humidity, and wind speed and direction. Aircraft position, heading, and altitude were also recorded, as were several radiometric observations for use in interpretation of the data (greenness index, surface temperature, incoming and reflected radiation). Data were collected at both the NSA and SSA during the three 1994 IFCs and in July and August of 1996. These data are stored in tabular ASCII files.

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#### 1. Data Set Overview

#### 1.1 Data Set Identification

BOREAS AFM-04 Twin Otter Aircraft Flux Data

#### 1.2 Data Set Introduction

The BOReal Ecosystem-Atmosphere Study (BOREAS) Airborne Fluxes and Meteorology (AFM)-04 team used the National Research Council (NRC) Twin Otter aircraft in 1994 and 1996 to make measurements in the boundary layer of the fluxes of sensible and latent heat, momentum, ozone, methane, and carbon dioxide, plus supporting meteorological parameters such as temperature, humidity, and wind speed and direction. Aircraft position, heading, and altitude were also recorded, as were several radiometric observations for use in interpretation of the data (greenness index, surface temperature, incoming and reflected radiation). Data were collected at both the Northern Study Area (NSA) and Southern Study Area (SSA) during the three 1994 Intensive Field Campaign (IFCs) and in July and August of 1996. These data are stored in tabular American Standard Code for Information Interchange (ASCII) files.

#### 1.3 Objective/Purpose

The Twin Otter was one of four flux aircraft operated in BOREAS. The purpose of its flights was to make measurements in the boundary layer of the fluxes of sensible and latent heat, momentum, ozone, methane, and carbon dioxide, plus supporting meteorological parameters such as temperature, humidity, and wind speed and direction. Aircraft position, heading, and altitude were also recorded, as were several radiometric observations for use in interpretation of the data (greenness index, surface temperature, incoming and reflected radiation). These data will be used to attempt to relate boundary layer processes (atmosphere/vegetation exchanges) to radiometric data available from satellites, i.e., ground truthing of satellite data. Through this research, it is hoped that techniques can be developed to utilize satellite data for global monitoring of climate change.

#### 1.4 Summary of Parameters

Temperature, dewpoint temperature, pressure, downwelling radiation, upwelling radiation, greenness index, three orthogonal components of the wind velocity, along-wind component, across wind component, H<sub>2</sub>O mixing ratio, CO<sub>2</sub> mixing ratio, ozone concentration, methane, sensible heat flux, latent heat flux, momentum flux, carbon dioxide flux, ozone flux, methane flux, aircraft position, heading, altitude (radar and pressure), surface temperature, satellite simulator.

#### 1.5 Discussion

The Twin Otter operated in all three IFCs in 1994. In 1994 the aircraft made 57 flights, including 1,100 flux runs. In 1996, a total of 27 project flights were made. The recorded data rate was increased from 16 Hz (as in 1994) to 32 Hz (for 1996), improving the resolution of the data contributing to the flux estimates. The archived data were collected on straight and level flux runs over the BOREAS site and on regional runs between Prince Albert and Thompson and in each project area. A variety of flight profiles are possible (grids, L- patterns, profiling stacks, soundings), which are described in Section 7.3. The archive data include run-averaged data, focusing on the fluxes and the supporting meteorological, radiometric, and aircraft positional data. No attempt was made to archive the high-rate (16-Hz or 32-Hz) data, which can be acquired from NRC directly, if required.

There was a significant difference in the instrumentation configuration on the Twin Otter for 1996 when compared with the 1994 campaign. It carried additional cloud physics and aerosol instruments belonging to the Atmospheric Environment Service (AES). These additional data are not included in this data set. Please consult MacPherson (1996) and MacPherson and Bastian (1997) for detailed information about the instrument configurations in 1994 and 1996.

#### 1.6 Related Data Sets

BOREAS AFM-01 NOAA/ATDD Long-EZ 1994 Aircraft Flux Data over the SSA

BOREAS AFM-02 Wyoming King Air 1994 Aircraft Flux and Moving Window Data

BOREAS AFM-03 NCAR Electra 1994 Aircraft Flux Data

BOREAS AFM-03 NCAR Electra 1994 Aircraft Moving Window Data

BOREAS AFM-04 NRC Twin Otter Aircraft Sounding Data

BOREAS AFM-05 Level-1 Upper Air Network Data

BOREAS AFM-05 Level-2 Upper Air Network Standard Pressure Level Data

BOREAS AFM-11 Aircraft Flux Analysis and Comparison PDF Documents

## 2. Investigator(s)

#### 2.1 Investigator(s) Name and Title

J. Ian MacPherson Flight Research Laboratory Institute for Aerospace Research National Research Council of Canada Ottawa, Ontario K1A OR6 Canada

Raymond L. Desjardins
Centre for Land and Biological Resources Research
Agriculture Canada
Building 74
Central Experimental Farm
Ottawa, Ontario K1A 0C6 Canada

#### 2.2 Title of Investigation

Atmospheric Boundary Layer Analyses from Canadian Twin Otter Aircraft

#### 2.3 Contact Information

#### Contact 1:

J. Ian MacPherson Bldg. U-61 National Research Council Ottawa, Ontario Canada K1A OR6 (613) 998-3014 (613) 952-1704 (fax) jim@u614ji.iar.nrc.ca

#### Contact 2:

David Knapp Raytheon ITSS NASA GSFC Code 923.4 Greenbelt, MD 20771 (301) 286-1424 (301) 286-0239 (fax) David.Knapp@gsfc.nasa.gov

## 3. Theory of Measurements

A series of reports addressing the theory and practice of measuring atmospheric variables from a moving, aircraft platform may be found in MacPherson (1981, 1988, 1990a, 1990b, 1992, 1996) and MacPherson and Bastian (1997).

A basic requirement for measuring gas fluxes from a moving aircraft is to account for the motion of the air relative to the motion of the aircraft. The true air motion is derived from the vector difference between the air velocity relative to the aircraft velocity relative to the ground.

Air motion relative to the aircraft is measured by a nose-mounted gust boom incorporating a Rosemount 858AJ28 5-hole probe. This device and the associated pressure transducers measure static pressure (altitude), dynamic pressure (airspeed), and the angles of attack and sideslip. These instruments in combination with a global positioning system (GPS) and an inertial reference system (IRS) are used to derive the flux measurements.

## 4. Equipment

#### 4.1 Sensor/Instrument Description

The Twin Otter atmospheric research aircraft is a highly instrumented platform for research on the atmospheric boundary layer, air pollution, etc. Descriptions of the aircraft and its instrumentation and software are given in detail in MacPherson (1981, 1988, 1990a, 1990b, 1996) and MacPherson and Bastian (1997).

Parameter Instrument

Sensible Heat Rosemount fast response 102DJ1CG

Incident Solar Radiation Kipp and Zonen CM-11 pyranometer (305-2800 nm range)

Reflected Solar Radiation Eppley pyranometer

Greenness Index Skye Industries Vegetation Greenness Indicator

Surface Temperature Barnes PRT-5 infrared radiometer Satellite Simulation Exotech 100BX Satellite Simulator

CO<sub>2</sub>, H<sub>2</sub>O LI-COR LI-6262 CO<sub>2</sub>/H<sub>2</sub>O analyzer (these CO<sub>2</sub> data reported to BORIS)

ESRI (developed by Agriculture Canada)

Dew Point E, G, and G Model 137-S10 Cambridge dew point sensor

Ozone TECO Ozone Analyzer Model 49 (these O<sub>3</sub> data reported to BORIS)

GFAS (unit borrowed from German Aerospace Research Establishment)

Scintrex LOZ-3 ozone detector

Momentum Wind Components

Inertial Velocity
Position
Altitude (AGL)
Litton LTN-90-100 Inertial Reference System
Trimble Model TNL-7880SR GPS/VLF/Omega
Sperry AA-200 Radio Altimeter (1994 and 1996)
Riegl LD-90-3 Laser Altimeter (1996 only)

Riegi ED 70 3 Easer Millioter (

#### 4.1.1 Collection Environment

The data were collected from the aircraft, flying at various altitudes.

#### 4.1.2 Source/Platform

Twin Otter DHC-6-200 twin turboprop utility transport.

Maximum gross takeoff weight 11,579 lb. Service ceiling 20,000 ft. Endurance 3 to 4 hours, depending on instrumentation and weather.

## 4.1.3 Source/Platform Mission Objectives

The primary objective was to measure the vertical flux of sensible and latent heat, CO<sub>2</sub>, ozone, methane, and momentum for scaling up surface-based measurements to regional scales. The ultimate objective is to develop algorithms to relate boundary layer processes to satellite-derived data.

#### 4.1.4 Key Variables

Temperature, dewpoint temperature, pressure, downwelling radiation, upwelling radiation, greenness index, three orthogonal components of the wind velocity, along-wind component, across wind component, H<sub>2</sub>O mixing ratio, CO<sub>2</sub> mixing ratio, ozone concentration, methane, sensible heat flux, latent heat flux, momentum flux, carbon dioxide flux, ozone flux, methane flux, aircraft position, heading, altitude (radar and pressure), surface temperature, satellite simulator.

#### 4.1.5 Principles of Operation

A basic requirement for measuring gas fluxes from a moving aircraft is to account for the motion of the air relative to the motion of the aircraft. The true air motion is derived from the vector difference between the air velocity relative to the aircraft velocity relative to the ground.

Air motion relative to the aircraft is measured by a nose-mounted gust boom incorporating a

Rosemount 858AJ28 5-hole probe. This device and the associated pressure transducers measure static pressure (altitude), dynamic pressure (airspeed), and the angles of attack and sideslip. These instruments in combination with a global positioning system (GPS) and an inertial reference system (IRS) are used to derive the flux measurements.

The principles of operation of the aircraft and its other instrumentation and software are given in detail in MacPherson (1981, 1988, 1990a, 1990b, 1996) and MacPherson and Bastian (1997).

#### 4.1.6 Sensor/Instrument Measurement Geometry

See MacPherson (1988, 1990a, 1990b, 1996) and MacPherson and Bastian (1997).

#### 4.1.7 Manufacturer of Sensor/Instrument

See Sections 4.1 and 6, and MacPherson (1988, 1990a, 1996) and MacPherson and Bastian (1997).

#### 4.2 Calibration

Instruments on the aircraft were calibrated prior to each IFC. Key instruments (such as temperature probes) were calibrated two or three times during each IFC.

#### 4.2.1 Specifications

Not available.

#### **4.2.1.1** Tolerance

Not available.

## 4.2.2 Frequency of Calibration

All instruments were calibrated at least once per IFC.

#### 4.2.3 Other Calibration Information

See MacPherson (1988, 1990a, 1990b, 1996) and MacPherson and Bastian (1997).

## 5. Data Acquisition Methods

There were several types of flight profiles. These are described in MacPherson (1988, 1990a, 1996) and MacPherson and Bastian (1997). Plotted flight tracks are shown for every flight. One hundred and twenty-eight channels of data are recorded digitally in 16-bit words at 16 samples per second (1994) or 32 samples per second (1996) on a Digital Archive Tape (DAT) drive. Most signals are low-pass filtered with a breakpoint of 5 Hz to prevent aliasing.

Fluxes are calculated using the procedures detailed in MacPherson (1990b, 1996) and MacPherson and Bastian (1997). It should be noted that in the final submission to the BORIS, three sets of flux and root mean square (RMS) data were submitted. The first used untreated time histories in the derivation of fluxes using the eddy correlation technique, the second used linearly detrended data, and the third used time histories that were high-pass filtered with a third-order algorithm with a break point set at 0.012 Hz (5 km wavelength). It is felt that most scientists working with these data would prefer to use the linearly detrended data. Data from the National Center for Atmospheric Research (NCAR) and University of Wyoming King Air aircraft were archived with the identical formats.

## 6. Observations

#### **6.1 Data Notes**

None.

#### **6.2 Field Notes**

Note: 128 channels of data are recorded digitally in 16-bit words at 16 samples per second on a DAT drive. Signals are low-pass filtered with a breakpoint of 5 Hz to prevent aliasing.

The following table lists the 128 recorded signals. Not all of these are archived to BORIS (see Section 8), but many contribute to calculated quantities such as true airspeed, wind velocity, fluxes, etc.

etc.
\*\*Note:\*\*\* This is basically the recorder buffer to be used in the site visit in May 1993. Additional parameters were recorded in BOREAS (e.g., satellite simulator). A Trimble global positioning system (GPS) replaced or augmented the Loran-C in 1994.

Channel	Variable		Resultion		
Number	<u>Name</u>	<u>Units</u>	(per bit)	<u>Instrument</u>	<b>Description</b>
1	<b>FILEHR</b>	hrs	1	NAE Clock	combined word, tape file and GMT hours
2	MINSEC	min/sec	1	NAE Clock	combined word, GMT minutes/ seconds
3	<b>EVENT</b>	-	1	Event Marker	multi-level event marker
4	LTD	deg	1	ARNAV Loran-C	latitude degrees
5	LTM	min	0.01	Model 40-AVA-100	latitude minutes
6	LGD	deg	1	Model 40-AVA-100	longitude degrees
7	LGM	min	0.01	Model 40-AVA-100	longitude minutes
8	LTML	min	0.01	Litton Inertial Ref	latitude minutes
				System, LTN-90-100	
9	LGML	min	0.01	Litton Inertial Ref	longitude minutes
				System, LTN-90-100	
10	HDGT	deg	0.1	Sperry C-12 Gyro	true heading (magnetic heading corrected to true
					heading using mag variation output from Loran-C)
11	HDGTL	dec	0.1	Litton 90 IRS	true heading, Litton
12	WDTI	deg	0.1	*Derived*	wind direction from doppler/ inertial system,
					degrees true (note 1)
13	WDTL	deg	0.1	*Derived*	from Litton system (see note 2)
14	WSMI	m/s	0.01	*Derived*	wind speed from doppler inertial system (note 1)
15	WSML	m/s	0.01	*Derived*	from Litton system (see note 2)
16	UGE	m/s	0.01	*Derived*	north/south wind component from doppler /inertial
					system, + from north
17	VGE	m/s	0.0	*Derived*	east/west, + from east
18	WGE	m/s	0.0	*Derived*	vertical wind, + up
19	LWN	m/s	0.0	*Derived*	north/south wind component from Litton system,
					(note 2), + from north
20	LWE	m/s	0.01	*Derived*	east/west wind component, + from east
21	WEP	m/s	0.01	*Derived*	vertical wind component
22	TSNBC	deg C	0.01	*Derived*	static temperature, derived from TAS & total temp
					(see ch 48) nose starboard temperature probe
23	DEWPTC	deg C	0.01	Egg Model 137	dew point
24	SDCTC	deg C	0.01	*Derived*	static temperature in CO <sub>2</sub> analyzer duct, derived
					from duct TAS & duct total temp; Rosemount 102
					probe
25	PRT5C	deg C	0.01	Barnes PRT-5	surface temperature
26	RADUP	w/m <sup>2</sup>	0.1	Kipp & Zonen CM-11	upward facing radiometer, measures incident
					radiation (see also note 3)

Channel	Variable		Resultion		
Number	Name	<u>Units</u>		Instrument	Description
27	RADOWN		0.1	Eppley Pyranometer-2	downward facing radiometer, measures reflected radiation
28	CO2NO2	mg/m <sup>3</sup>	0.1	Ag Canada ESRI CO <sub>2</sub> /H <sub>2</sub> O Analyzer	carbon dioxide conc, 20 Hz response, low pass filtered at 5.5 Hz for anti-aliasing
29	H2O	$g/m^3$	0.01	Ag Canada ESRI CO <sub>2</sub> /H <sub>2</sub> O Analyzer	water vapor conc
30	RALT	m	0.1	Sperry AA-200 Radio Altimeter	height above ground
31	TASFK	kts	0.1	*Derived*	true airspeed, fuselage probes
32	TASNBK	kts	0.1	*Derived*	true airspeed, noseboom probes
33	TASDCT	kts	0.1	*Derived*	true airspeed in CO <sub>2</sub> /H <sub>2</sub> O analyzer duct
34	PSDUCT	mb	0.1	A.I.R. AIR-DB-2C	static pressure in duct
35	PSNBC	mb	0.1	Paroscientific 215L-AW-01 2	static pressure, noseboom, corrected for position error
36	TSFC	deg C	0.01	*Derived*	static temperature, derived from tas and total temp measured by fuselage port rosemount probe (see channel 47)
37	GRNRAT	-	0.001	Skye Industries SKR-100	greenness ratio, 730 nm signal/660 nm signal
38	VDTM	m/s	0.1	Decca Doppler Radar-72	ground speed, total vector from doppler radar
39	GSL	kts	0.1	Litton 90 IRS	ground speed, total vector from Litton
40	LCCO2	mv	1.0	LI-COR 6262	CO <sub>2</sub> concentration, recorded as millivolts, converted to ppm
41	LCTSC	deg C	0.01	LI-COR 6262	temperature in licor analyzer test cell
42	UGEIL	m/s	0.01	*Derived*	north/south wind component from doppler/Litton system, + from north
43	<b>VGEIL</b>	m/s	0.01	*Derived*	east/west, + from east
44	WGEIL	m/s	0.01	*Derived*	vertical wind, + up
45	LCH2O	mv	1.0	LI-COR 6262	H <sub>2</sub> O concentration recored as millivolts, converted to ppt
46	WFIL	m/s	0.01	*Derived*	high-pass filtered vertical wind for eddy accumulation system
47	TTF	deg K	0.01	Rosemount 102DJ1CG	total temperature, fast response, port fuselage probe
48	TTNB	deg K	0.01	Rosemount 102DJ1CG	total temperature, fast response, starboard fuselage probe
49	PSFC	mb	0.1	Rosemount 1201F1B4A1 B	static pressure, fuselage ports, corrected for positi on error.
50	METHAN	ppb	1.0	Unisearch TDL Methane Analyzer	methane concentration
51					not used
52	TECO	ppb	0.1	TECO-49 Ozone Analyzer	ozone concentration, slow response for mean concentrations
53	OZD	ppb	0.1	German GFAS OS- G-2 Ozone Analyzer	ozone concentration fast response (>10 Hz)
54	DOZD	ppb	0.01	German GFAS OS- G-2 Ozone Analyzer	hi-sensitivity ozone fluctuations from start of flux run
55	UCO2N2	$mg/m^3$	0.1	Ag Canada ESRI CO <sub>2</sub> /H <sub>2</sub> O Analyzer	raw CO <sub>2</sub> unfiltered

Channel	Variable		Resultion		
Number	Name	<u>Units</u>		Instrument	Description
56	UH20N2	g/m <sup>3</sup>	0.01	Ag Canada ESRI	raw H <sub>2</sub> O unfiltered
				CO <sub>2</sub> /H <sub>2</sub> O Analyzer	_
57	THETAL	deg	0.01	Litton-90 IRS	pitch attitude + nose up
58	PHIL	deg	0.01	Litton-90 IRS	roll attitude + right wing down
59	VXMLTN		1/128	Decca Doppler	along-heading component of ground speed, positive
				Radar-72	forward, corrected to position of Litton-90 IRS
60	VYMLTN	m/s	1/256	Decca Doppler Radar-72	across-heading component of ground speed, positive starboard, corrected to position of Litton-90 IRS
61	VZMLTN	m/s	1/512	Decca Doppler	vertical component of aircraft velocity relative to grnd
				Radar-72	+ down, corrected to position of Litton-90 IRS
62	ULN	m/s	0.01	Litton-90 IRS	north/south inertial velocity, + to north.
63	VLE	m/s	0.0	Litton-90 IRS	east/west inertial velocity, + to east
64	WZL	m/s	0.0	Litton-90 IRS	vertical inertial velocity, + down
65	PDF	mb	0.01	Rosemount Transducer 1221F-2VL7 A1A	
66	PDNB	mb	0.01	Rosemount Transducer 1221F-1V7A 1B	dynamic pressure, noseboom pitot uncorrected for p.e.
67	PSF	mb	0.10	Rosemount Transducer 1201F-1B4A 1B	static pressure, fuselage ports, uncorrected for p.e.
68	PSNBLR	mb	0.10	Paroscientific	static pressure, noseboom, corrected to lab standard,
				215L-AW-01 2	uncorrected for p.e.
69	PD	mb	0.01	*Derived*	dynamic pressure used (PDNB or PDF) in real time software selected by function switch
70	PDFNB	mb	0.01	*Derived*	dynamic pressure from fuselage port corrected to noseboom position, used as PDNB backup
71	EACONT	bits	1.0	*Derived*	signal that controls eddy accumulation system,1000 when WFIL is up, -1000 when WFIL is down, zero in dead zone
72	TS	deg C	0.01	*Derived* (TSFC or TSNBC)	static temperature used in real time software, selected by function switch
73	GRN660	-	0.01	Skye Industries SKR-100	660 nm signal from SKR-100 greenness device
74	GRN730	-	0.01	Skye Industries SKR-100	730 nm signal from SKR-100 greenness device
75	TSPARO	deg F	0.01	Paroscientific 215L-AW-01 2	transducer temperature used to correct static pressure signal
76	WGAI	m/s	0.01	*Derived*	vertical wind, doppler system, a/c axes
77	LALT	ft	1.0	Litton 90/100 IRS	absolute height
78	PALT	ft	1.0	*Derived*	pressure height, uses PSNBC
79	LTDL	deg	1.0	Litton 90/100 IRS	Litton latitude, deg only
80	LTDL	deg	1.0	Litton 90/100 IRS	Litton longitude, deg only
81	PDFC	mb	0.01	Rosemount Transducer 1221F-2VL7 A1A	ē .
82	PDNBC	mb	0.01		dynamic pressure, noseboom pitot corrected for p.e.
83	VX	knots	0.10	Decca Doppler Radar-72	ground speed, x component a/c axes, + forward
84	VY	knots	0.10	Decca Doppler Radar-72	ground speed, y component a/c axes, + to starboard
85	VX	knots	0.10	Decca Doppler Radar-72	ground speed, z component a/c axes, + down

Channel	Variable		Resultion		
Number	Name	Units		Instrument	Description
86	THETA	deg	0.01	Kearfott Attitude Gyro, T2109	attitude pitch, + nose up
87	PHI	deg	0.01	Kearfott Attitude Gyro, T2109	attitude roll, + right wing down
88	AZL	$m/s^2$	0.01	Litton 90/100 Irs	vertical acceleration, a/c axes,+ a/c down
89	EAZL	$m/s^2$	0.01	Litton 90/100 IRS	vertical acceleration earth axes, +a/c down
90	UAIRN	m/s	1/128	*Derived*	north component of true airspeed (TAS) vector
91	VAIRE	m/s	1/128	*Derived*	east component of true airspeed (TAS) vector
92	WAIRZ	m/s	1/128	*Derived*	vertical component of true airspeed (TAS) vector, + a/c down
93	UAIR	m/s	1/128	*Derived*	x-axis TAS component
94	VAIR	m/s	1/128	*Derived*	y-axis TAS component
95	WAIR	m/s	1/128	*Derived*	z-axis TAS component
96	UANAE	m/s	1/128	*Derived*	x-axis TAS component, corrected to NAE accelerometer location
97	VANAE	m/s	1/128	*Derived*	y-axis TAS component, corrected to NAE\
					accelerometer location
98	WANAE	m/s	1/128	*Derived*	z-axis TAS component, corrected to NAE accelerometer location
99	UALTN	m/s	1/128	*Derived*	x-axis TAS component, corrected to Litton IRS location
100	VALTN	m/s	1/128	*Derived*	y-axis TAS component, corrected to Litton IRS
101	WALTN	m/s	1/128	*Derived*	location z-axis TAS component, corrected to Litton IRS
102	UMIX7	m/s	1/128	*Derived*	location x inertial velocity component from NAE/doppler
103	VMIX7	m/s	1/128	*Derived*	system y inertial velocity component from NAE/doppler
104	WA AIN		1/100	*D	system
104	WMIX7	m/s	1/128	*Derived*	z inertial velocity component from NAE/doppler system
105	PDDUCT	mb	0.01	Rosemount Transducer 12211F-2VL7 A1A	dynamic pressure in CO <sub>2</sub> measurement duct
106	ALPHA	deg	0.01	Rosemount 858AJ28 & Transducer 12211F-1VL5 A1	angle of attack probe measured by 5 hole probe on noseboom
107	BETA	deg	0.01	Rosemount 858AJ28 & Transducer 12211F-1VL5 A1	angle of side-probe & slip measured by 5 hole probe on noseboom.
108	UDOTN	$m/s^2$	1/128	*Derived*	derivative of x inertial velocity from NAE/doppler system
109	VDOTN	m/s <sup>2</sup>	1/128	*Derived*	derivative of y inertial velocity from NAE/doppler system
110	WDOTN	m/s <sup>2</sup>	1/128	*Derived*	derivative of z inertial velocity from NAE/doppler
111	UGAI	m/s	0.01	*Derived*	system longitudinal wind, doppler system, a/c axes
111	VGAI	m/s	0.01	*Derived*	lateral wind, doppler system, a/c axes
112	PALFNB	mb	0.01	Rosemount Transducer	differential pressure angle of attack ports
113	TALIND	IIIU	0.01	12211F-1VL5 A1 R-858	arresentar pressure argie of attack ports
114	UGAIL	m/s	0.01	*Derived*	longitudinal wind, Litton/doppler system, a/c axes
115	VGAIL	m/s	0.01	*Derived*	lateral wind, Litton/doppler system, a/c axes

Channel	Variable		Resultion		
Number	<u>Name</u>	<u>Units</u>	(per bit)	<b>Instrument</b>	<b>Description</b>
116	WGAIL	m/s	0.01	*Derived*	vertical wind, Litton/doppler system, a/c axes
117	AXL	$m/s^2$	0.01	Litton 90/100 IRS	longitudinal acceleration, a/c axes, + a/c fwd
118	AYL	$m/s^2$	0.01	Litton 90/100 IRS	lateral acceleration, a/c axes, + a/c starboard
119	<b>PBETNB</b>	mb	0.01	Rosemount Transducer	differential pressure angle of sideslip ports
				12211F-1VL5A1	
				R-858	
120	AX	$m/s^2$	0.01	Systron Donner 4211	longitudinal acceleration, a/c axes, backup system
121	AY	$m/s^2$	0.01	Systron Donner 4211	lateral acceleration, a/c axes
122	AX	$m/s^2$	0.01	Systron Donner 4211	vertical acceleration, a/c axes
123	PRATEL	deg/s	0.01	Litton 90/100 IRS	roll rate, + right wing down
124	QRATEL	deg/s	0.01	Litton 90/100 IRS	pitch rate, + nose up
125	RRATEL	deg/s	0.01	Litton 90/100 IRS	yaw rate, + nose right
126	PRATE	deg/s	0.01	Smiths Gyros	roll rate, + right wing down
				402-RGA	
127	QRATE	deg/s	0.01	Smiths Gyros	pitch rate, + nose up
				02-RGA	
128	RRATE	deg/s	0.01	Smiths Gyros	yaw rate, + nose right
				402-RGA	

NOTE 1: This is the backup, or alternative, wind measuring system in case the Litton 90/100 inertial reference system (IRS) should fail. Calculation of wind components is described in reports by MacPherson (1988, 1990a, 1990b, 1996) and MacPherson and Bastian (1997). The air velocity relative to the aircraft is measured by the true air speed (TAS) and noseboom angles of attack and sideslip. The aircraft inertial velocity relative to Earth is measured in aircraft axes by a system incorporating complementary filtering in real time on the aircraft microprocessor. A system of accelerometers and rate gyros provides the high-frequency components to this filter; the Decca 3-axis Doppler radar provides the low-frequency components. The resulting calculated velocity components in a/c axes are subtracted from the TAS components to get the three components of winds in a/c axes. These are then resolved into Earth axes using the pitch and roll attitude and the aircraft heading to get uge, vge, and wge (channels 16-18).

**NOTE 2:** The primary wind system uses a Litton 90/100 IRS to measure the aircraft inertial velocity components in 3 Earth axes. The IRS is similar to an INS (Inertial Navigation System), but measures the velocities, accelerations and rates in aircraft axes as well as Earth axes. This is also used to derive wind given in channels 11, 13, 15, 19, 20, 21, 42, 43, and 44 above. Numerous tests have been done to compare flux data derived with these two different wind measuring systems on the Twin Otter. Some of this appears in MacPherson (1990a, 1996). These studies reveal that fluxes derived with the older Doppler-based system appear to be underestimated by 10-15 percent. The Litton based wind should be used whenever possible (channels 19, 20, 21, 13, and 15).

**NOTE 3:** MacPherson (1988, 1990b, 1996) gives a description of a routine used to correct the radup reading for aircraft attitude changes.

#### 1996 Flights

There may be some steps in some of the analog channels; Most obvious in high-altitude inputs and tests; Required further investigation. It appears that the ESRI and LICOR are slightly motion dependent, producing small additional downward CO<sub>2</sub> flux for ESRI, upward for LICOR.

There is a sawtooth on the WAIRZ that originates from the basic resolution of the digiquartz transducers, PALPHA, PBETA and PDNB. The PDNB is quite steppy when compared with the Rosemount for PDF. The range of the PDNB is too high (0-12 psi, which good for about 700 knots!). It should be replaced with one that does no more than 0-1 psi, or at least that of the PALPHA and PBETA transducers.

Satellite simulator in MSS mode, 1 deg field of view for Flights 58-62,

in SPOT 15-deg field of view for Flights 63-69 in MSS mode, 15 deg field of view, Flights 70-83

- NOTE: In flux re-analysis with Kalman filtering and ground-calculated winds, the TASNB used in most flights was low by about 0.3 mps. When TASF was used for Flight 65, it was low by 1.3 mps; For Flights 66- when TASF used, then correction factor of 1.3 was applied in airborne program, so no additional adjustment would be required except when working right from pressure data (recalculated in TASFUSE)
- Bias required to beta of +0.35 for all flights except Flt 75, in which it should be 0.54
- TASF will be low by 1.3 mps until Flight 66, for which a bias was added to the airborne program
- TASNB will be low by 0.3 mps until Flight 67, for which a bias was added to the airborne program
- TASNB low by 1.10 mps on Flight 67, possibly due to loose connection on transducer
- For Flight 68 TAS bias removed from airborne program, but biases added to PDNB of 0.4 mb, and to PDF of 1.2 mb: PDNB bias changed to +0.2 for Flight 69 and subsequent flights
- Temperatures start to diverge about Flight 72, with TSPort greater than starboard, increasing to 1.0 deg by Flight 78.
- NOTE: BOREAS airborne program was inadvertently using old noseboom PE values, not new ones derived on May 16 test flights: In recalculation, run PLOTPOK96\_new with correct PE's, then re-run the reciprocal wind checks to get new biases for TAS and Beta. Data suggests that old PE's may be the more accurate. Need to do verification of May 16 PE's on another flight.
- NOTE: Also have noticed that the PDFNB is using the new PE's (0.904\*PDFC); To match the old PE's used in the other calculations, 0.936 should be used. Airborne program changed to 0.936 on August 1 before Flight 78
- RADUP reads -6 while in hangar; add bias in REDEF programs
- GPS has lag of several seconds; must adjust in ARCPOK96\_new
- TECO possibly reads 3 ppb high; Must check all zeros for each individual flight prior to final archive round of flux calculations.
- NOTE: Greenness index is not necessarily associated with healthy plants and good CO<sub>2</sub> uptake on Ag run, for Canola indicates a greenness index of 1.9, when it is at least as developed as wheat fields giving 3.2-3.5
- LICOR spikes caused by spikes in PSLICOR; affects CO<sub>2</sub> more than H<sub>2</sub>O.

The following table indicates instrument status during the flights in 1996.

Date	Flight #	Instrument Status
09-JUL-96	58	<ul> <li>GPS quit twice, first enroute from YPA to W to start Ag run, second in last run of first grid (approx 1755 GMT). Returned to normal at 1808.</li> <li>LOZ3 ozone analyzer u/s most of flight, turned off for part of flight</li> <li>NO/NO<sub>2</sub> analyzer reads high throughout flight, although recorded reading is perhaps only a tenth of what was shown on face of unit.</li> <li>ESRI CO<sub>2</sub>/H<sub>2</sub>O analyzer intermittent, but H<sub>2</sub>O OK after Run 14; CO<sub>2</sub> signal looks OK except for Runs 13 and 14 when unit turned off</li> <li>Reciprocal runs suggest TAS low by 0.5 mps; apply this bias in re-calc</li> <li>DLR ozone analyzer has spikes and poor correlation with TECO; Not useable</li> <li>Laser altimeter drops to below zero in several spikes, perhaps an indication of a signal or error level.</li> </ul>
	59	<ul> <li>NO/NO<sub>2</sub> analyzer possibly u/s throughout flight</li> <li>LOZ3 recycled off/on in sounding (Run 01), but then OK rest of flight; use 1.0 slope when doing fluxes from regression against TECO</li> <li>Reciprocal runs suggest TASNB low by 0.45 mps</li> </ul>
10-JUL-96	60	<ul> <li>GPS quit at 1754 Z for about 4 minutes. Caused abort of Run 13 at OJP</li> <li>TASNB appears to be low by 0.4 mps</li> <li>ESRI H<sub>2</sub>O signal unusable for Run 09; spikes</li> <li>NO/NO<sub>2</sub> analyzer not correct, drifting downwards through flight from 20 ppb</li> <li>Time lost 20 sec at start-up, so IAR time behind AES and cameras by about 20 seconds</li> </ul>
11-JUL-96	61	<ul> <li>GPS quit at 1751 for a few minutes</li> <li>NO/NO<sub>2</sub> analyzer u/s</li> <li>Time 20 seconds behind cameras, but synchronized with AES DAS</li> <li>TASNB appears low by about 0.3 mps</li> <li>Note: CO<sub>2</sub> and H<sub>2</sub>O analyzers calibrated prior to this flight</li> <li>LICOR CO<sub>2</sub> has some spikes and seems noisy and poorly correlated with the ESRI during the OBS runs late in the flight.</li> </ul>
12-JUL-96	62	<ul> <li>GPS problem, recycled Off/On at 1745 GMT; Problem identified as poor satellite configuration</li> <li>DLR ozone analyzer turned off at 1743 due to rain on Run 04</li> <li>LOZ3 power supply failed, so unit operated on battery but failed at 1853 Z in Run 11</li> <li>ESRI CO<sub>2</sub> should be distrusted on several runs when rain encountered.</li> <li>NO/NO<sub>2</sub> analyzer removed from aircraft</li> </ul>

14-JUL-96	63	<ul> <li>Satellite Simulator changed to SPOT Mode, Gains set at B=5, C=25, and D=5: D is limiting at about 42 W/m² only over Ag Run</li> <li>Flew into rain on Run 10; DLR selected OFF at 1740</li> <li>DLR signal alive for first 9 runs, but biased off to near zero concentration for unknown reason</li> <li>AES DAS quit at 1649 GMT</li> <li>GPS outage again most of time between 1725 and 1740 GMT</li> <li>New routine to hold Laser_alt constant when signal drops below zero. Unit does not work over water</li> <li>Runs 5-11 across Candle Lake include 2 n miles of forest before and after the lake surface, thus the flux calculated over the whole event will not be accurate; Runs must be subdivided to get fluxes for water only.</li> <li>Good agreement between the ESRI and LICOR CO<sub>2</sub> fluxes, but the LICOR H<sub>2</sub>O fluxes quite a bit smaller than the ESRI.</li> <li>NO/NO<sub>2</sub> analyzer removed from aircraft</li> <li>Reciprocal Ag runs suggest TASNB too low, as in previous flights.</li> </ul>
15-JUL-96	64	<ul> <li>ABORT Flight due to failure of P_Alpha pressure transducer, therefore no vertical gust capability</li> <li>NO/NO<sub>2</sub> analyzer removed from aircraft</li> </ul>
	65	<ul> <li>TEST Flight; Temporary pressure transducer configuration:</li> <li>P_beta transducer (0-3 PSID) moved to P_alpha position</li> <li>Noseboom PD transducer (0-12 PSID) moved to P-beta position</li> <li>NO PDNB or TASNB recorded</li> <li>Winds and static temperature use TAS_F (i.e., F/S 2 ON)</li> <li>Alpha and Beta use PDFNB (i.e., F/S 3 ON)</li> <li>TAS_F reads 1.3 mps low</li> <li>Beta bias of -0.4 deg: Add 0.4 deg to beta (which already has an additional 0.35 deg)</li> <li>Greenness Index sensors not turned on</li> <li>NO/NO<sub>2</sub> analyzer removed from aircraft</li> <li>DLR ozone analyzer reads near zero throughout flight</li> <li>Magnetic heading mis-set until 1910.</li> <li>PSNBC incorrect; not corrected for Position Error</li> </ul>
19-JUL-96	66	<ul> <li>Pressure transducers back in usual configuration</li> <li>Beta bias again to add 0.35, and TASNB add 0.3 mps</li> <li>DLR instrument not flown</li> <li>NO/NO<sub>2</sub> analyzer removed from aircraft</li> <li>GPS out at 1715 at end of Run 06 and through Run 07</li> <li>First flight with bias of 1.3 mps added to TASF</li> <li>First flight with Laser altimeter updating at 50 Hz</li> </ul>

20-JUL-96	67	<ul> <li>First flight with bias of 0.3 mps added to TASNB</li> <li>TASNB was low by 1.1 mps, possibly due to loose connection on transducer</li> <li>Also discovered that airborne program was using old noseboom PE's, rather than new ones derived on May 16 test flight. Will leave that way until end of program</li> <li>PSduct appears to be 3 mb high.</li> <li>NO/NO<sub>2</sub> analyzer on aircraft, but NO<sub>2</sub> signal seems highly correlated with altitude.</li> </ul>
	68	<ul> <li>For this flight (and subsequent ones), the TAS bias was removed and instead, a bias was added to PDNB (0.4 mb) and PDF (1.2 mb) to bring them to zero while at zero airspeed in the hangar.</li> <li>Reciprocal data from each grid gives the same TAS error; 0.37 mps should be subtracted from TASNB. Beta bias less than 0.1 deg.</li> <li>Run 12 was wrong line (FR-FP instead of FR-FQ); Was repeated</li> <li>GPS locked up on last run of first grid (Run 11); run may have been extended a bit too far east.</li> <li>GPS out between grids; Poor satellite configuration</li> <li>PDNBC has little steps that are not identical to PDNB, even on ramp.</li> <li>Care with fluxes: There are trends and discontinuities in some of the runs for CO<sub>2</sub> and H<sub>2</sub>O, perhaps due to large clouds just west of grid.</li> </ul>
23-JUL-96	69	<ul> <li>ABORT flight; generator out, then brake fire</li> <li>PDNB bias set to +0.2 this and subsequent flights; PDF bias remains at +1.2</li> </ul>
25-JUL-96	T-11	<ul> <li>GPS not turned on, and heater circuit breakers pulled</li> <li>Generator failure on takeoff; abort rest of flight</li> <li>No DAT tape</li> </ul>
	T-12	Generator test: GPS not used; no DAT tape
26-JUL-96	70	<ul> <li>GPS from Convair 580 installed after Flight 69; first project use this flight</li> <li>GPS intentionally left OFF until after takeoff in case there was a generator problem; selected ON at about 1942Z, a minute after takeoff</li> <li>Satellite Simulator in MSS Mode, 15 deg, gains 5,5,5,1</li> <li>DLR ozone analyzer not installed this flight</li> <li>PSDUCT checked and found 3 mb high on landing.</li> <li>Event marker off too short time between Runs 01 and 02: Flux program groups them together, so need to re-run by event time</li> <li>LICOR H<sub>2</sub>O plotted vs ESRI had slope of about 0.85, and resulted in low fluxes compared to ESRI. Prior to this flight, a major calibration was performed on LICOR with many test gases to answer 480 vs 422 problem. No problem was found, but now slope seems low compared to ESRI.</li> </ul>

27-JUL-96	71	<ul> <li>GPS intentionally left OFF until after takeoff in case there was a generator problem; selected ON at about 1655Z, a minute after takeoff</li> <li>DLR ozone analyzer not flown</li> <li>Runs 20 and 21 through rain shower, may affect ESRI CO<sub>2</sub>/H<sub>2</sub>O fluxes</li> <li>Time 20 seconds behind cameras, but aligned with AES DAS</li> <li>GPS into Standby for about a minute after Ag Run 01</li> <li>NB: LICOR H<sub>2</sub>O fluxes seemed low compared to ESRI, and even compared to those from DewPt: LICOR H<sub>2</sub>O cospectrum has funny shape, with peak at wavelength different from either LICOR CO<sub>2</sub> or ESRI H<sub>2</sub>O.</li> <li>Spikes and/or dropouts in ESRI H<sub>2</sub>O signal on at least one run; Must check all runs for H<sub>2</sub>O spikes, especially since there is concern about its comparison with the LICOR H<sub>2</sub>O.</li> </ul>
29-JUL-96	72	<ul> <li>GPS intentionally left OFF until after takeoff in case there was a generator problem; selected ON at about 1513Z, a minute after takeoff</li> <li>First flight with difference in static pressures; PSNBC greater than PSFC by 1.8 mb; PSFC later proven to be the errant one- Time 20 seconds behind cameras, but synchronized with AES DAS</li> <li>LICOR H<sub>2</sub>O could be low on first 3 or 4 runs</li> <li>Cospectra indicate that LICOR calibration too low, or ESRI too high</li> <li>GPS went into Standby at 1720Z at end of Run 18; selected OFF then ON</li> <li>Spikes in ESRI H<sub>2</sub>O signal</li> </ul>
	73	<ul> <li>Time 20 seconds behind the cameras, but synchronized with AES DAS</li> <li>Static pressure difference; PSFC about 2.5 mb too low</li> </ul>
30-JUL-96	74	<ul> <li>Time 20 seconds behind the cameras, but synchronized with AES DAS</li> <li>There is a 2.5 mb difference in PSFC and PSNBC (PSFC probably too low)</li> <li>GPS went into Standby enroute to 'A'</li> </ul>
	75	<ul> <li>Time 20 seconds behind the cameras, but synchronized with AES DAS</li> <li>There is a 2.5 mb difference in PSFC and PSNBC (PSFC probably too low)</li> <li>NO/NO<sub>2</sub> device off scale high</li> </ul>

31-JUL-96	76	<ul> <li>Time 20 seconds behind the cameras, but synchronized with AES DAS</li> <li>There is a 2.5 mb difference in PSFC and PSNBC. Ground check August 01 indicate PSFC is errant transducer</li> <li>NO/NO<sub>2</sub> device off scale high</li> <li>Standard deviation of ESRI CO<sub>2</sub> signal was high relative to LICOR on several runs, (eg., Run 22); Large spikes in ESRI occasionally, H<sub>2</sub>O and CO<sub>2</sub> (Run 5)</li> <li>LICOR CO<sub>2</sub> signal suspect. seems to lack high frequency, like the H<sub>2</sub>O signal of Flight 71. Also, see notes on Flight 77 re: the LICOR CO<sub>2</sub> lag, LICOR span also found low on August 01 calibration</li> <li>For some reason, the TAS bias has dropped to zero</li> </ul>
	77	<ul> <li>Time 20 seconds behind the cameras, but synchronized with AES DAS</li> <li>There is a 2.5 mb difference in PSFC and PSNBC</li> <li>NO/NO<sub>2</sub> device off scale high</li> <li>The difference between the LICOR and ESRI CO<sub>2</sub> fluxes seems larger than usual; check cospectra; LICOR CO<sub>2</sub> has many spikes. Also, Run 02 has positive LICOR CO<sub>2</sub> flux when ESRI negative. Data compared with Harry McCaughey at YJP, LE's agreed, but his CO<sub>2</sub> fluxes agreed well with ESRI (his -0.23, ours ESRI -0.215), and NOT the LICOR (-0.04)</li> <li>Cospectra show that LICOR CO<sub>2</sub> very suspect (see Run 6); Also, the LICOR CO<sub>2</sub> signal seems to require a different lag than the H<sub>2</sub>O, which is very unusual. The CO<sub>2</sub> signal looks like it should have only been lagged 8 time slices, rather than 19 like the H<sub>2</sub>O: Found out August 4 that this is due to pressure used in conversion from ppm to concentration. Mixing ratio lags OK</li> <li>Data archived using ESRI for CO<sub>2</sub> flux, but LICOR for H<sub>2</sub>O</li> <li>When calibrated Aug. 1, the span was low on the LICOR CO<sub>2</sub> by approximately 10 percent.</li> <li>LICOR Ser. 649 removed from aircraft after this flight and replaced by LICOR Ser. 703</li> <li>For some reason, the TAS bias has dropped to zero</li> </ul>
01-AUG-96	78	<ul> <li>First flight with LICOR Ser. 703</li> <li>LICOR CO<sub>2</sub> fluxes larger, but still well below ESRI</li> <li>Also, LICOR H<sub>2</sub>0 fluxes low, particularly on 100' runs; Low at all frequencies, suggesting calibration has low span</li> <li>Data archived using ESRI for H20 flux, but LICOR for CO<sub>2</sub></li> <li>GPS total failure at 1847Z prior to first run</li> <li>No AES data recorded this flight</li> <li>There is a 2.5 mb difference in PSFC and PSNBC</li> <li>PDFNB factor changed to old values of 0.936 PSFC</li> <li>PSFC less than PDNBC</li> <li>Port temperature greater than Starboard</li> </ul>

02-AUG-96	79	<ul> <li>LICOR fluxes very low compared to ESRI: regression of 32-Hz data suggest calibration sensitivity too low when compared with ESRI. On some runs at YJP, LICOR CO<sub>2</sub> trace very different than ESRI. LICOR CO<sub>2</sub> trace trails ESRI by about 1/2 second, while H<sub>2</sub>O is OK.</li> <li>PSFC less than PDNBC</li> <li>Port temperature greater than Starboard by about 2 deg C.</li> <li>Time 20 seconds behind the cameras, but synchronized with AES DAS</li> <li>Turned ESRI instrument OFF at 1751 after sounding since nitrogen was getting low</li> <li>DLR ozone analyzer has some large excursions that are not duplicated by LOZ3 or TECO</li> </ul>
03-AUG-96	80	<ul> <li>First Flight with LICOR Ser. # 176 (same unit flown in 1994, still using Dec. 1993 calibration constants)</li> <li>LICOR CO<sub>2</sub> fluxes still well below those of ESRI, and became near zero at end of flight, as in Flight 79</li> <li>LICOR H<sub>2</sub>O span adjusted in flight right after takeoff; set to approximate data from aircraft dew point sensor. Was reading about 5 gm/Kg high until then (approx. 1610 Z)</li> <li>PSFC still about 2 mb less than PSNBC</li> <li>Temperature probes cleaned and recalibrated prior to this flight.</li> <li>Time 20 seconds behind the cameras, but synchronized with AES DAS</li> <li>Evidence of steps in most analog channels, most clearly seen in high altitude runs where signals are clean (see pitches)</li> </ul>
05-AUG-96	81	<ul> <li>LICOR calibrated before flight; also filter and filter line replaced; old unit had possible small leak at connector</li> <li>PSFC less than PSNBC by about 2 mb</li> <li>DLR ozone device matched LOZ3 in flight for first time in quite some time; CWT cleaned unit after last flight</li> <li>Airborne LICOR subroutine changed before this flight: The CO<sub>2</sub> and H<sub>2</sub>O concentrations in mg/m³ and gm/m³ respectively are now calculated using the PS_LICOR and LC_TEMP instead of the noseboom pressure and temperature.</li> <li>Evidence of steps in most analog channels, most clearly seen in high altitude runs where signals are clean (see pitches)</li> </ul>
06-AUG-96	T-13	<ul> <li>TEST FLIGHT with ESRI dust closed and 'bagged'; LICOR still plumbed to duct</li> <li>PSFC lower than PSNBC by about 2 mb</li> <li>DLR ozone analyzer not installed</li> </ul>
07-AUG-96	82	<ul> <li>PSFC lower than PSNBC by about 2 mb</li> <li>DLR ozone analyzer turned OFF at 1545 Z due to rain</li> <li>Time about 20 seconds behind camera, but synchronized with AES DAS</li> </ul>
08-AUG-96	83	<ul> <li>PSFC lower than PSNBC by about 2 mb</li> <li>DLR ozone analyzer not flown this flight</li> <li>Time about 20 seconds behind camera, but synchronized with AES DAS</li> </ul>

## **Summary of 1996 Fluxes**

## Southern Study Area (SSA)

Date DoY	Flight	Site	Time [GMT]	Runs #1	Wind [d /mps]	Temp [degC]	H [W /m <sup>2</sup> ]	LE #3 [W /m <sup>2</sup> ]	BR	CO <sub>2</sub> #4 [mg /m <sup>2</sup> /s]	Oz [ug /m²/s]	NetR [W/m <sup>2</sup> ]
09-Jul-96 191	58	Grid Grid	1730 1845	9	197/5.0 198/5.0	19.4 20.0	190 222	208 212	0.91 1.05	-0.39 -0.30	-	679 712
	59	OA	2130	6	182/5.5	20.3	104	270	0.39	-0.73	-0.32	506
10-Jul-96 192	60	OBS OJP	1715 1800	8 7	133/6.0 119/5.2	21.3 22.3	183 224	193 214	0.95 1.05	-0.24 -0.28	-0.31 -0.37	616 644
11-Jul-96 193	61	OA OBS	1715 1845	9 6	012/2.4 036/3.9	20.7 22.3	74 168	313 180	0.23 0.93	-0.81 -0.19	-0.44 -0.10	573 583
14-Jul-96 196	63	Ag Lake	1815 1730	7 7	256/3.8 231/2.5	21.4 20.6	42 1	339 25	0.12 0.06	-0.88 0.00	-0.25 0.00	616
19-Jul-96 201	66	OA	1700	6	202/5.6	17.4	120	268	0.45	-0.79	-0.59	615
20-Jul-96	67	Lake	1145	6	124/2.0	13.7	7	59	0.12	+0.14	-0.04	-
202	68	Grid Grid	1630 1745	9	158/3.2 187/2.6	17.5 19.3	152 199	153 247	0.99 0.81	-0.38 -0.39	-0.17 -0.17	557 693
26-Jul-96 208	70	OA	2045	6	165/2.1	18.0	84	215	0.39	-0.82	-0.35	381
27-Jul-96 209	71	Grid Grid OBS	1745 1845 1915	9 9 2	131/3.9 155/4.5 166/4.9	16.9 17.2 17.1	47 42 33	121 #5 125 50	0.39 0.34 0.65	-0.49 6 -0.43 -0.21	-0.34 -0.34 -0.17	311 #6 245 64
29-Jul-96 211	72	OBS Grid Grid	1600 1700 1745	8 9 9	174/1.8 148/1.5 152/1.8	18.6 19.4 20.5	130 134 149	160 187 227	0.82 0.71 0.66	-0.33 -0.37 -0.40	-0.26 -0.24 -0.26	500 578 621
	73	OA	2015	7	177/2.5	22.3	23	173	0.13	-0.43	-0.17	212 #7

<sup>#</sup>I - Only nominal 100' runs #3 - From LICOR

Note: Fluxes computed with linearly detrended data with Kalman-corrected winds, as archived

<sup>#4 -</sup> From LICOR

<sup>#5 -</sup> LICOR H<sub>2</sub>O suspiciously low this day

<sup>#6 -</sup> Overcast this day

<sup>#7 -</sup> Clouds over; decreasing radiation study

## Northern Study Area (NSA)

Date DoY	Flight #	Site	Time [GMT]	Runs	Wind [d/mps]	Temp [degC]	H [W /m <sup>2</sup> ]	LE [W /m <sup>2</sup> ]	BR	CO <sub>2</sub> [mg /m <sup>2</sup> /s]	Oz [ug /m²/s]	NetR [W/m <sup>2</sup> ]
31-Jul-96 213	76	Grid Grid OBS OJP	1515 1615 1700 1730	9 9 5 8	203/3.6 219/4.3 222/3.9 218/4.3	23.3 24.3 25.0 25.3	92 132 196 237	150 190 135 96	0.61 0.70 1.45 2.46	-0.23 -0.22 -0.19 -0.09	-0.03 -0.09 0.01 0.00	450 527 586 609
	77	Burn YJP Burn	1915 1945 2000	4 8 5	216/5.4 222/5.0 212/5.5	26.1 26.5 26.3	81 175 90	171 75 211	0.47 2.32 0.43	-0.27 #8 -0.22 -0.34	-0.20 -0.03 -0.25	439 368 479
01-Aug-96 214	78	Burn	1900	4	200/6.4	24.3	64	185 #9	0.35	-0.29	-0.16	317
02-Aug-96 215	79	Grid Grid OBS OJP YJP	1500 1600 1645 1715 1745	9 9 5 8 6	225/4.6 235/5.4 233/5.7 228/6.1 230/7.5	23.6 24.8 25.7 26.1 26.4	62 106 148 200 206	172 150 170 83 124	0.36 0.71 0.87 2.41 1.66	-0.22 -0.16 -0.19 -0.07 -0.09	-0.18 -0.16 -0.16 -0.12 -0.10	431 515 599 554 575
03-Aug-96 216	80	Grid Grid OBS YJP	1630 1730 1815 1845	9 9 6 5	100/3.5 115/3.2 127/3.5 104/3.4	25.1 25.9 26.7 27.0	135 162 205 174	167 145 159 67	0.81 1.12 1.28 2.60	-0.26 -0.17 -0.18 -0.02	-0.15 -0.16 -0.18 -0.05	509 554 591 418
05-Aug-96   218	81	OJP Grid Grid OJP	1600 1645 1745 1815	6 9 9 6	201/3.6 195/3.9 196/4.3 203/4.4	21.6 22.2 23.1 23.1	141 138 129 68	148 222 180 101	0.95 0.62 0.62 0.67	-0.13 -0.27 -0.31 -0.11	-0.21 -0.30 -0.17 -0.16	510 538 462 182
07-Aug-96 220	82	OBS #2 OBS #2 Burn	1500 1545 1645	4 4 6	295/4.6 280/4.6 295/6.5	12.9 13.5 13.6	48 87 61	143 190 135	0.33 0.46 0.45	-0.29 -0.36 -0.34	-0.31 -0.33 -0.17	283 296 207 #10
08-Aug-96 221	83	Grid Grid OBS	1515 1615 1700	9 9 6	004/4.1 009/4.0 014/3.7	9.2 10.1 11.1	88 144 183	88 116 136	1.00 1.24 1.35	-0.43 -0.51 -0.50	-0.17 -0.22 -0.19	272 400 482

<sup>#2</sup> - Flux divergence or advection study, only 30 m runs shown #8 - ESRI  $CO_2$  fluxes used Flt 77

Note: Fluxes computed with linearly detrended data using Kalman-corrected winds: as archived

<sup>#9 -</sup> ESRI LE fluxes used Flt 78

<sup>#10 -</sup> Increasing cloud

## 7. Data Description

## 7.1 Spatial Characteristics

### 7.1.1 Spatial Coverage

Grid flight patterns consisted of twin sets (one in the NSA and one in the SSA) of nine parallel lines flown at 100 feet above ground level (AGL) at a 2-km spacing covering a 16- by 16-km area. For each of these grids, two flight plans were stored in the aircraft's GPS system; one with the east/west lines, and one with the north/south lines. On a given day, the wind direction was measured and the flight pattern that was closest to cross wind was chosen. Since turbulent eddies are elongated in the direction of the wind, crosswind tracks encounter more eddies; thus, the determination of the flux is statistically more reliable. On each grid flight, the grid pattern was flown twice, with the repeated pass flown in the opposite direction to the first. In this way, each pair of runs on a given line can be examined for possible biases in wind measurement or other variables. The double grid pattern took nearly 2 hours to fly. Some regional runs were also flown, for example, from Prince Albert to Nipawin, Saskatchewan. Very long regional runs were flown (at approximately 500 feet) on the transit flights between Prince Albert (near the SSA) and Thompson (in the NSA).

The two 16-km grids fall within the NSA and SSA. The North American Datum of 1983 (NAD83) corner points for these grid patterns are:

SSA		
	Latitude	Longitude
Northeast	53.930° N	104.565° W
Northwest	53.930° N	104.810° W
Southwest	53.787° N	104.810° W
Southeast	53.787° N	104.565° W
NSA		
	Latitude	Longitude
Northeast	55.947° N	98.397° W
Northwest	55.947° N	98.653° W
Southwest	55.803° N	98.653° W
Southeast	55.803° N	98.397° W

In their 1996 report, AFM-04 reported the following waypoints for non-grid runs.

	Waypoint 1		Way	point 2	
Site	Lat.	Long.	Lat.	Long.	Comments
OA - SSA	53 34.9	-106 16.8	53 38.4	-106 09.6	About 11 km, homogeneous vegetation
OBS - SSA	53 59.0	-105 08.2	53 57.8	-104 56.0	14.5 km, mostly spruce, tower near west end
OJP - SSA	53 53.6	-104 44.2	53 56.0	-104 39.5	Only 6 km homog., so marginal for TS
Agricultural Run	53 21.0	-105 28.8	53 31.0	-105 28.9	18.5 km, pasture, canola and wheat
Extended Ag to forest	53 31.0	-105 28.9	53 41.0	-105 29.0	18.5 km interface from Ag to forest
Full Candle Lake Run	53 34.7	-106 23.8	53 59.0	-104 47.2	115 km, Heterogeneous, 3 lakes
Candle Lake Run for morning Flight 67	53 49.8	-105 27.9	53 51.6	-105 12.9	14 km run across Candle lake
OBS - NSA	55 52.5	-98 22.5	55 52.4	-98 34.0	12 km good sfc.
OJP - NSA	55 55.6	-98 37.7	55 56.6	-98 36.2	3 km homog. veg, marginal for TN
Burn - NSA	55 49.7	-98 19.4	55 51.6	-98 30.0	11 km all burned; used for almost all runs in 1994
YJP - NSA	55 53.8	-98 16.4	55 54.2	-98 18.8	< 3km, marginal for flux

Flux runs were also made over Candle Lake over a length of 115 km. These runs were made to cover a heterogeneous track across the study area in order to see how flux varies over different land cover types.

En route from the Prince Albert Airport to the area of the flux towers in the boreal forest, an agricultural area was overflown consisting mostly of pasture, rapeseed, and wheat. To collect data to monitor fluxes over the whole growing season in an agricultural area, a 20-km north/south track was selected in this area. This was flown by the Twin Otter at a 30-m altitude on 40 occasions during the three IFCs in 1994.

On 08-Sept-1994, a 500-km flux run was made along the transect between the NSA and SSA from 1640 to 2040 Greenwich Mean Time (GMT).

#### 7.1.2 Spatial Coverage Map

None.

#### 7.1.3 Spatial Resolution

The spatial resolution of the original data used in the flux computations is a function of the aircraft speed (approximately 55 m/s) and the digital recording rate (16 Hz in 1994, 32 Hz in 1996) and the anti-alias filtering applied to the data prior to recording (5.5 Hz). This translates to a basic sampling resolution of approximately 12 m (1994) and 6 m (1996) for the Twin Otter.

## 7.1.4 Projection

None. These data were collected at point locations.

## 7.1.5 Grid Description

The data were collected at point locations, primarily in a regular grid pattern. The grid spacing was approximately 2 km.

## 7.2 Temporal Characteristics

#### 7.2.1 Temporal Coverage

In 1994, data were collected on the following dates:

```
In 1994, data were collected on the following dates:
IFC-1: 25-May-1994 to 27-May-1994
       29-May-1994
        31-May-1994 to 01-Jun-1994
        04-Jun-1994
        06-Jun-1994 to 11-Jun-1994
        13-Jun-1994
IFC-2: 20-Jul-1994 to 29-Jul-1994
        01-Aug-1994 to 02-Aug-1994
        04-Aug-1994
        08-Aug-1994
IFC-3: 31-Aug-1994 to 03-Sep-1994
        06-Sep-1994
        08-Sep-1994
        11-Sep-1994 to 19-Sep-1994
In 1996, data were collected on the following dates:
        06-Jul-1996 to 07-Jul-1996
        09-Jul-1996 to 12-Jul-1996
        14-Jul-1996 to 15-Jul-1996
        19-Jul-1996 to 20-Jul-1996
        23-Jul-1996
        25-Jul-1996 to 27-Jul-1996
        29-Jul-1996 to 31-Jul-1996
        01-Aug-1996 to 03-Aug-1996
        05-Aug-1996 to 10-Aug-1996
```

SSA \* number of runs of each type

Doto		<b>A</b> ~	Intf		T 46			S	pecif	fic Si	ite	Flux			
Date 1996	Flight	Ag W-X	X-Y	CL	Grid	OA	BS	JP	Fen	Budget	Trans	Other	Snd		
Jul 09	58	2	2	-	18	-	-	-	-	-	-	-	2		
Jul 09	59	-	-	-	-	6	-	-	-	-	-	-	1		
Jul 10	60	2	2	-	-	-	8	7	-	-	-	-	1		
Jul 11	61	1	1	1	-	9	6	-	-	-	-	-	1		
Jul 12	62	2	2	-	-	_	-	-	-	11	-	-	1		
Jul 14	63	8	2	-	-	-	-	-	-	-	-	7	2		
Jul 15	65	2	-	-	-	-	-	-	-	-	-	-	-		
Jul 19	66	-	-	-	-	6	-	-	-	-	-	-	1		
Jul 20	67	-	-	-	-	-	2	-	-	-	-	16	3		
Jul 20	68	2	-	-	18	-	-	-	-	-	-	-	1		
Jul 26	70	1	-	1	-	6	-	-	-	-	-	1	1		
Jul 27	71	1	-	-	18	-	2	-	-	-	-	-	1		
Jul 29	72	2	-	-	18	-	8	-	-	-	-	-	2		
Jul 29	73	1	-	-	-	7	-	-	-	-	-	8	1		
Jul 30	74	-	-	1	-	-	-	-	-	-	1	-	2		
	17	24	9	3	72	34	26	7	-	11	1	32	20		

## $\underline{NSA}$

Dodo				Specif	ic Site					
Date 1996	Flight	Grid	burn	BS	OJP	YJP	м-о	Trans	Other	Snd
Jul 30	75	-	-	6	-	-	1	1	-	1
Jul 31	76	18	-	5	8	-	-	-	2	2
Jul 31	77	-	9	-	-	8	-	-	-	1
Aug 01	78	-	8*	-	-	-	-	-	-	-
Aug 02	79	18	-	5	8	6	-	-	-	2
Aug 03	80	18	-	6	-	5	-	-	4	1
Aug 05	81	18	-	-	12	-	-	-	6	3
Aug 07	82	-	6	12	-	-	-	-	4	2
Aug 08	83	18	-	6	-	-	-	-	-	1
	09	90	23	40	28	19	1	1	16	13

CL: 62 nm Candle Lake

Snd: Sounding

Trans: transect PA/Flin Flon (SSA) Flin Flon/Thompson (NSA)

\* 4 runs at 100', 4 at 500'

## 7.2.2 Temporal Coverage Map

None.

## 7.2.3 Temporal Resolution

The aircraft data were recorded at a basic rate of 16 Hz (1994) or 32 Hz (1996). Flight durations were typically 3 to 3.5 hours. On several occasions there were two flights per day.

#### 7.3 Data Characteristics

#### 7.3.1 Parameter/Variable

The parameters contained in the data files on the CD-ROM are:

Column Name

\_\_\_\_\_

SPATIAL\_COVERAGE

RUN START DATE

RUN\_START\_TIME

RUN END DATE

RUN\_END\_TIME

FLUX\_MISSION\_DESIGNATOR

FLUX MISSION NUM

FLUX PASS NUM

FLUX SEGMENT NUM

START\_LATITUDE

START\_LONGITUDE

END\_LATITUDE

END LONGITUDE

START\_BOREAS\_X

START\_BOREAS\_Y

END\_BOREAS\_X

END\_BOREAS\_Y

**HEADING** 

MEAN\_PRESS\_ALTITUDE

MEAN RADAR ALTITUDE

MEAN\_WIND\_DIR

MEAN\_WIND\_SPEED

MEAN\_AIR\_TEMP

MEAN POTNTL TEMP

MEAN\_H2O\_MIX\_RATIO

MEAN\_U\_COMPNT\_WIND\_VELOC

MEAN\_V\_COMPNT\_WIND\_VELOC

MEAN\_STATIC\_PRESS

MEAN SURF RAD TEMP

MEAN\_DOWN\_TOTAL\_RAD

MEAN\_UP\_TOTAL\_RAD

MEAN\_DOWN\_LONGWAVE\_RAD

MEAN\_UP\_LONGWAVE\_RAD

MEAN\_NET\_RAD

MEAN UP PPFD

MEAN\_DOWN\_PPFD

MEAN AUX RAD

MEAN\_GREEN\_INDEX

MEAN\_CO2\_CONC

MEAN\_O3\_CONC

MEAN\_CH4\_CONC

MEAN\_SAT\_SIM\_CH1

MEAN\_SAT\_SIM\_CH2

MEAN\_SAT\_SIM\_CH3

MEAN\_SAT\_SIM\_CH4

SDEV AIR TEMP

SDEV\_POTNTL\_TEMP

SDEV H2O MIX RATIO

SDEV\_U\_COMPNT\_WIND\_VELOC

SDEV\_V\_COMPNT\_WIND\_VELOC

SDEV STATIC PRESS

SDEV\_SURF\_RAD\_TEMP

SDEV\_DOWN\_TOTAL\_RAD

SDEV UP TOTAL RAD

SDEV\_DOWN\_LONGWAVE\_RAD

SDEV UP LONGWAVE RAD

SDEV NET RAD

SDEV\_UP\_PPFD

SDEV\_DOWN\_PPFD

SDEV\_AUX\_RAD

SDEV GREEN INDEX

SDEV\_CO2\_CONC

SDEV 03 CONC

SDEV\_CH4\_CONC

SDEV SAT SIM CH1

SDEV\_SAT\_SIM\_CH2

SDEV\_SAT\_SIM\_CH3

SDEV SAT SIM CH4

TREND AIR TEMP

TREND\_POTNTL\_TEMP

TREND\_H2O\_MIX\_RATIO

TREND U COMPNT WIND VELOC

TREND\_V\_COMPNT\_WIND\_VELOC

TREND STATIC PRESS

TREND\_SURF\_RAD\_TEMP

TREND DOWN TOTAL RAD

TREND\_UP\_TOTAL\_RAD

TREND\_DOWN\_LONGWAVE\_RAD

TREND\_UP\_LONGWAVE\_RAD

TREND GREEN INDEX

TREND\_CO2\_CONC

TREND\_O3\_CONC

TREND CH4 CONC

SDEV VERT GUST RAW

SDEV\_U\_COMPNT\_WIND\_VELOC\_RAW

SDEV\_V\_COMPNT\_WIND\_VELOC\_RAW

SDEV\_ALONG\_WIND\_RAW

SDEV\_CROSS\_WIND\_RAW

SDEV POTNTL TEMP RAW

SDEV\_H2O\_MIX\_RATIO\_RAW

SDEV CO2 MIX RATIO RAW

SDEV\_O3\_CONC\_RAW

SDEV\_CH4\_CONC\_RAW

SKEW VERT GUST RAW

SKEW\_U\_COMPNT\_WIND\_VELOC\_RAW

SKEW V COMPNT WIND VELOC RAW

SKEW\_ALONG\_WIND\_RAW

SKEW\_CROSS\_WIND\_RAW

SKEW\_POTNTL\_TEMP\_RAW

SKEW H2O MIX RATIO RAW

SKEW\_CO2\_MIX\_RATIO

SKEW 03 CONC RAW SKEW\_CH4\_CONC\_RAW KURT VERT GUST RAW KURT U COMPNT WIND VELOC RAW KURT V COMPNT WIND VELOC RAW KURT\_ALONG\_WIND\_RAW KURT CROSS WIND RAW KURT\_POTNTL\_TEMP\_RAW KURT H2O MIX RATIO RAW KURT CO2 MIX RATIO RAW KURT O3 CONC RAW KURT\_CH4\_CONC\_RAW CORC\_VERT\_U\_WIND\_COMPNT\_RAW CORC VERT V WIND COMPNT RAW CORC VERT ALONG WIND RAW CORC VERT CROSS WIND RAW CORC\_VERT\_POTNTL\_TEMP\_RAW CORC VERT H20 MIX RATIO RAW CORC\_VERT\_CO2\_MIX\_RATIO\_RAW CORC VERT O3 CONC RAW CORC VERT CH4 CONC RAW MMNTM\_FLUX\_V\_WIND\_COMPNT\_RAW

CORC POTNTL H2O MIX RATIO RAW

MMNTM\_FLUX\_U\_WIND\_COMPNT\_RAW MMNTM FLUX ALONG MEAN WIND RAW

MMNTM FLUX CROSS MEAN WIND RAW SENSIBLE HEAT FLUX RAW

LATENT\_HEAT\_FLUX\_RAW

CO2 FLUX RAW

O3\_FLUX\_RAW

O3 DEPOSITION VELOC RAW

CH4 FLUX RAW

AIR DENSITY CONSTANT

SPECIFIC HEAT CONSTANT

LATENT\_HEAT\_VAP\_CONSTANT

DRY AIR GAS CONSTANT

SDEV VERT GUST DET

SDEV U COMPNT WIND VELOC DET

SDEV\_V\_COMPNT\_WIND\_VELOC\_DET

SDEV ALONG WIND DET

SDEV\_CROSS\_WIND\_DET

SDEV POTNTL TEMP DET

SDEV H2O MIX RATIO DET

SDEV CO2 MIX RATIO

SDEV\_O3\_CONC\_DET

SDEV\_CH4\_CONC\_DET

SKEW VERT GUST DET

SKEW U COMPNT WIND VELOC DET

SKEW V COMPNT WIND VELOC DET

SKEW\_ALONG\_WIND\_DET

SKEW CROSS WIND DET

SKEW\_POTNTL\_TEMP\_DET

SKEW H2O MIX RATIO DET

SKEW\_CO2\_MIX\_RATIO\_DET

SKEW\_O3\_CONC\_DET SKEW\_CH4\_CONC\_DET KURT VERT GUST DET KURT\_U\_COMPNT\_WIND\_VELOC\_DET KURT V COMPNT WIND VELOC DET KURT\_ALONG\_WIND\_DET KURT CROSS WIND DET KURT\_POTNTL\_TEMP\_DET KURT H2O MIX RATIO DET KURT\_CO2\_MIX\_RATIO\_DET KURT O3 CONC DET KURT\_CH4\_CONC\_DET CORC\_VERT\_U\_WIND\_COMPNT\_DET CORC VERT V WIND COMPNT DET CORC\_VERT\_ALONG\_WIND\_DET CORC VERT CROSS WIND DET CORC\_VERT\_POTNTL\_TEMP\_DET CORC\_VERT\_H2O\_MIX\_RATIO\_DET CORC\_VERT\_CO2\_MIX\_RATIO\_DET CORC VERT O3 CONC DET CORC\_VERT\_CH4\_CONC\_DET CORC\_POTNTL\_H2O\_MIX\_RATIO\_DET MMNTM\_FLUX\_U\_WIND\_COMPNT\_DET MMNTM\_FLUX\_V\_WIND\_COMPNT\_DET MMNTM FLUX ALONG MEAN WIND DET MMNTM\_FLUX\_CROSS\_MEAN\_WIND\_DET SENSIBLE HEAT FLUX DET LATENT\_HEAT\_FLUX\_DET CO2\_FLUX\_DET O3\_FLUX\_DET O3 DEPOSITION VELOC DET CH4\_FLUX\_DET CRTFCN CODE REVISION\_DATE

#### 7.3.2 Variable Description/Definition

The descriptions of the parameters contained in the data files on the CD-ROM are:

Column Name	Description
SPATIAL_COVERAGE	The general term used to denote the spatial area over which the data were collected.
RUN_START_DATE	The date in GMT at the beginning of the segment (or pass if not segmented) in the form DD-MON-YY.
RUN_START_TIME	The time in GMT at the beginning of the segment (or pass if not segmented).
RUN_END_DATE	The date in GMT at the end of the segment (or pass if not segmented) in the form DD-MON-YY.
RUN_END_TIME	The time in GMT at the end of the segment (or pass if not segmented).
FLUX_MISSION_DESIGNATOR	The two-letter mission identifier used to identify the type of mission being flown, where GS or GN=grids and stacks, CS=Candle Lake runs,

LN=mini- or meso-transects, PS or PN=Budget Box pattern, HS or HN=stacks and tees, FS or FN=flights of two for intercomparison, ZS=lowlevel routes, and XX=not standard. FLUX\_MISSION\_NUM The sequential number for all missions flown on a given day starting at 1. FLUX\_PASS\_NUM The sequential pass number within a mission starting at 1. FLUX SEGMENT NUM The segment number within the current pass starting at 1 or given as 0 if pass is not segmented. START\_LATITUDE The NAD83 based latitude coordinate at the start of the measurement set. START LONGITUDE The NAD83 based longitude coordinate at the start of the measurement set. END\_LATITUDE The NAD83 based latitude coordinate at the end of the measurement set. END\_LONGITUDE The NAD83 based longitude coordinate at the end of the measurement set. START BOREAS X The x component of the BOREAS grid coordinate at the start of the measurement set. START\_BOREAS\_Y The y component of the BOREAS grid coordinate at the start of the measurement set. END BOREAS X The x component of the BOREAS grid coordinate at the end of the measurement set. END BOREAS Y The y component of the BOREAS grid coordinate at the end of the measurement set. **HEADING** The aircraft heading. MEAN\_PRESS\_ALTITUDE The mean pressure altitude. The mean radar altitude. MEAN RADAR ALTITUDE The mean direction from which the wind was MEAN WIND DIR traveling, increasing in a clockwise direction from the north for the given time over the period defined by the start and end dates. The mean wind speed for the given time over the MEAN WIND SPEED period defined by the start and end dates. MEAN AIR TEMP The mean air temperature. MEAN\_POTNTL\_TEMP The mean potential temperature. MEAN H2O MIX RATIO The mean water vapor mixing ratio. MEAN\_U\_COMPNT\_WIND\_VELOC The mean westerly vector component of the wind speed and wind direction. The mean southerly vector component of the wind MEAN\_V\_COMPNT\_WIND\_VELOC speed and wind direction. MEAN STATIC PRESS The mean static pressure. MEAN\_SURF\_RAD\_TEMP The mean surface radiative temperature. MEAN\_DOWN\_TOTAL\_RAD The mean downwelling total radiation. MEAN\_UP\_TOTAL\_RAD The mean upwelling total radiation. MEAN DOWN LONGWAVE RAD The mean downward longwave radiation. The mean upwelling longwave radiation. MEAN\_UP\_LONGWAVE\_RAD MEAN NET RAD The mean net radiation.

TS or TN=site-specific runs, RT=transects, LS or

density.

The mean upward photosynthetic photon flux

The mean downward photosynthetic photon flux

MEAN\_UP\_PPFD

MEAN\_DOWN\_PPFD

density. MEAN\_AUX\_RAD The mean measurement from the auxiliary radiation sensor. MEAN GREEN INDEX The mean greenness index. MEAN CO2 CONC The mean carbon dioxide concentration. MEAN\_O3\_CONC The mean ozone concentration. MEAN CH4 CONC The mean methane concentration. The mean channel 1 satellite simulator. MEAN\_SAT\_SIM\_CH1 MEAN SAT SIM CH2 The mean channel 2 satellite simulator. The mean channel 3 satellite simulator. MEAN SAT SIM CH3 MEAN SAT SIM CH4 The mean channel 4 satellite simulator. The standard deviation of the air temperature. SDEV AIR TEMP The standard deviation of potential temperature. SDEV\_POTNTL\_TEMP SDEV H2O MIX RATIO The standard deviation of the water vapor mixing ratio. The standard deviation of the westerly vector SDEV U COMPNT WIND VELOC component of the wind speed and wind direction. SDEV\_V\_COMPNT\_WIND\_VELOC The standard deviation of the southerly vector component of the wind speed and wind direction. SDEV STATIC PRESS The standard deviation of the static pressure. SDEV\_SURF\_RAD\_TEMP The standard deviation of the surface radiative temperature. The standard deviation of downwelling total SDEV\_DOWN\_TOTAL\_RAD radiation. SDEV UP TOTAL RAD The standard deviation of upwelling total radiation. The standard deviation of the downward longwave SDEV DOWN LONGWAVE RAD radiation. SDEV UP LONGWAVE RAD The standard deviation of upwelling longwave radiation. SDEV NET RAD The standard deviation of the mean net radiation. The standard deviation of the upward SDEV\_UP\_PPFD photosynthetic photon flux density. SDEV\_DOWN\_PPFD The standard deviation of the downward photosynthetic photon flux density. The standard deviation of the measurements from SDEV AUX RAD the auxiliary radiation sensor. The standard deviation of greenness index. SDEV GREEN INDEX SDEV CO2 CONC The standard deviation of the CO2 concentration. The standard deviation of the ozone SDEV\_O3\_CONC concentration. SDEV CH4 CONC The standard deviation of CH4 concentration. The standard deviation of the channel 1 satellite SDEV\_SAT\_SIM\_CH1 simulator values. The standard deviation of channel 2 satellite SDEV\_SAT\_SIM\_CH2 simulator values. The standard deviation of channel 3 satellite SDEV SAT SIM CH3 simulator values. The standard deviation of channel 4 satellite SDEV SAT SIM CH4 simulator values. TREND AIR TEMP The trend in air temperature. TREND\_POTNTL\_TEMP TREND\_H2O\_MIX\_RATIO The trend in potential temperature.

TREND\_U\_COMPNT\_WIND\_VELOC

The trend in water vapor mixing ratio.

The trend in the westerly vector component of

TREND\_V\_COMPNT\_WIND\_VELOC The trend in the southerly vector component of the wind speed and wind direction. TREND STATIC PRESS The trend in static pressure. TREND SURF RAD TEMP The trend in surface radiative temperature. TREND\_DOWN\_TOTAL\_RAD The trend in the downwelling total radiation. TREND UP TOTAL RAD The trend in the upwelling total radiation. The trend in the downwelling longwave radiation. TREND\_DOWN\_LONGWAVE\_RAD TREND UP LONGWAVE RAD The trend in the upwelling longwave radiation. TREND GREEN INDEX The trend in the greenness index. TREND CO2 CONC The trend in the carbon dioxide concentration. The trend in the ozone concentration. TREND\_O3\_CONC The trend in the methane concentration. TREND\_CH4\_CONC SDEV VERT GUST RAW The standard deviation of the raw vertical gust. SDEV U COMPNT WIND VELOC RAW The standard deviation of the raw westerly wind component. SDEV\_V\_COMPNT\_WIND\_VELOC\_RAW The standard deviation of the raw southerly wind component. SDEV\_ALONG\_WIND\_RAW The standard deviation of the raw along wind component. The standard deviation of the raw cross wind SDEV\_CROSS\_WIND\_RAW component. SDEV\_POTNTL\_TEMP\_RAW The standard deviation of the raw potential temperature. SDEV H2O MIX RATIO RAW The standard deviation of the raw water vapor mixing ratio. SDEV CO2 MIX RATIO RAW The standard deviation of the raw carbon dioxide mixing ratio. SDEV 03 CONC RAW The standard deviation of the raw ozone concentration. SDEV CH4 CONC RAW The standard deviation of the raw methane concentration. SKEW VERT GUST RAW The skewness of the raw vertical gust. SKEW U COMPNT WIND VELOC RAW The skewness of the raw westerly wind component. SKEW\_V\_COMPNT\_WIND\_VELOC\_RAW The skewness of the raw southerly wind component. The skewness of the raw along wind component. SKEW ALONG WIND RAW SKEW CROSS WIND RAW The skewness of the raw cross wind component. SKEW POTNTL TEMP RAW The skewness of the raw potential temperature. SKEW\_H2O\_MIX\_RATIO\_RAW The skewness of the raw water vapor mixing ratio. SKEW\_CO2\_MIX\_RATIO The skewness of the raw carbon dioxide mixing ratio. SKEW O3 CONC RAW The skewness of the raw ozone concentration. SKEW\_CH4\_CONC\_RAW The skewness of the raw methane concentration. KURT\_VERT\_GUST\_RAW The kurtosis of the raw vertical gust. KURT\_U\_COMPNT\_WIND\_VELOC\_RAW The kurtosis of the raw westerly wind component. KURT\_V\_COMPNT\_WIND\_VELOC\_RAW The kurtosis of the raw southerly wind component. The kurtosis of the raw along wind component. KURT ALONG WIND RAW KURT CROSS WIND RAW The kurtosis of the raw cross wind component. KURT POTNTL TEMP RAW The kurtosis of the raw potential temperature. KURT\_H2O\_MIX\_RATIO\_RAW The kurtosis of the raw water vapor mixing ratio. KURT\_CO2\_MIX\_RATIO\_RAW The kurtosis of the raw carbon dioxide mixing ratio. KURT O3 CONC RAW The kurtosis of the raw ozone concentration. The kurtosis of the raw methane concentration. KURT\_CH4\_CONC\_RAW

the wind speed and wind direction.

The correlation coefficient of the raw vertical CORC\_VERT\_U\_WIND\_COMPNT\_RAW gust/westerly wind component pair. CORC VERT V WIND COMPNT RAW The correlation coefficient of the raw vertical gust/southerly wind component pair. CORC\_VERT\_ALONG\_WIND\_RAW The correlation coefficient of the raw vertical gust/along wind component pair. CORC\_VERT\_CROSS\_WIND\_RAW The correlation coefficient of the raw vertical gust/cross wind component pair. CORC\_VERT\_POTNTL\_TEMP\_RAW The correlation coefficient of the raw vertical gust/potential temperature pair. CORC\_VERT\_H2O\_MIX\_RATIO\_RAW The correlation coefficient of the raw vertical gust/water vapor mixing ratio pair. CORC\_VERT\_CO2\_MIX\_RATIO\_RAW The correlation coefficient of the raw vertical qust/carbon dioxide mixing ratio pair. CORC\_VERT\_O3\_CONC\_RAW The correlation coefficient of the raw vertical qust/ozone concentration pair. The correlation coefficient of the vertical gust CORC\_VERT\_CH4\_CONC\_RAW /methane concentration pair. CORC\_POTNTL\_H2O\_MIX\_RATIO\_RAW The correlation coefficient of the raw potential temperature/water vapor mixing ratio pair. MMNTM\_FLUX\_V\_WIND\_COMPNT\_RAW The momentum flux using the raw southerly wind component. MMNTM\_FLUX\_U\_WIND\_COMPNT\_RAW The momentum flux using the raw westerly wind component. MMNTM FLUX ALONG MEAN WIND RAW The momentum flux using the raw along mean wind component. MMNTM FLUX CROSS MEAN WIND RAW The momentum flux using the raw across mean wind component. SENSIBLE HEAT FLUX RAW The raw sensible heat flux. LATENT\_HEAT\_FLUX\_RAW The raw latent heat flux. The raw carbon dioxide flux. CO2 FLUX RAW The raw ozone flux. O3 FLUX RAW O3\_DEPOSITION\_VELOC\_RAW The raw ozone deposition velocity. The raw methane flux. CH4\_FLUX\_RAW AIR\_DENSITY\_CONSTANT The constant used for air density in the flux calculations. SPECIFIC HEAT CONSTANT The constant used for specific heat at constant pressure in the flux calculations. LATENT\_HEAT\_VAP\_CONSTANT The constant used for latent heat of vaporization in the flux calculations. DRY\_AIR\_GAS\_CONSTANT The dry air gas constant used in the flux calculations. SDEV\_VERT\_GUST\_DET The standard deviation of the detrended vertical gust. SDEV\_U\_COMPNT\_WIND\_VELOC\_DET The standard deviation of the detrended westerly wind component. SDEV V COMPNT WIND VELOC DET The standard deviation of the detrended southerly wind component. SDEV\_ALONG\_WIND\_DET The standard deviation of the detrended along wind component. SDEV\_CROSS\_WIND\_DET The standard deviation of the detrended cross wind component. SDEV POTNTL TEMP DET The standard deviation of the detrended potential temperature.

SDEV\_H2O\_MIX\_RATIO\_DET The standard deviation of the detrended water vapor mixing ratio. The standard deviation of the detrended carbon SDEV CO2 MIX RATIO dioxide mixing ratio. SDEV 03 CONC DET The standard deviation of the detrended ozone concentration. SDEV CH4 CONC DET The standard deviation of the detrended methane concentration. SKEW VERT GUST DET The skewness of the detrended vertical gust. The skewness of the detrended westerly wind SKEW\_U\_COMPNT\_WIND\_VELOC\_DET component. SKEW\_V\_COMPNT\_WIND\_VELOC\_DET The skewness of the detrended southerly wind component. SKEW ALONG WIND DET The skewness of the detrended along wind component. SKEW CROSS WIND DET The skewness of the detrended cross wind component. SKEW\_POTNTL\_TEMP\_DET The skewness of the detrended potential temperature. SKEW H2O MIX RATIO DET The skewness of the detrended water vapor mixing ratio. SKEW\_CO2\_MIX\_RATIO\_DET The skewness of the detrended carbon dioxide mixing ratio. The skewness of the detrended ozone SKEW\_O3\_CONC\_DET concentration. SKEW CH4 CONC DET The skewness of the detrended methane concentration. KURT\_VERT\_GUST\_DET The kurtosis of the detrended vertical gust. KURT\_U\_COMPNT\_WIND\_VELOC\_DET The kurtosis of the detrended westerly wind component. KURT\_V\_COMPNT\_WIND\_VELOC\_DET The kurtosis of the detrended southerly wind component. KURT\_ALONG\_WIND\_DET The kurtosis of the detrended along wind component. KURT\_CROSS\_WIND\_DET The kurtosis of the detrended cross wind component. KURT POTNTL TEMP DET The kurtosis of the detrended potential temperature. KURT\_H2O\_MIX\_RATIO\_DET The kurtosis of the detrended water vapor mixing ratio. KURT\_CO2\_MIX\_RATIO\_DET The kurtosis of the detrended carbon dioxide mixing ratio. The kurtosis of the detrended ozone KURT\_O3\_CONC\_DET concentration. The kurtosis of the detrended methane KURT\_CH4\_CONC\_DET concentration. The correlation coefficient of the detrended CORC VERT U WIND COMPNT DET vertical gust/westerly wind component pair. CORC\_VERT\_V\_WIND\_COMPNT\_DET The correlation coefficient of the detrended vertical gust/southerly wind component pair. CORC\_VERT\_ALONG\_WIND\_DET The correlation coefficient of the detrended vertical gust/along wind component pair. CORC VERT CROSS WIND DET The correlation coefficient of the detrended vertical gust/cross wind component pair.

The correlation coefficient of the detrended CORC\_VERT\_POTNTL\_TEMP\_DET vertical gust/potential temperature pair. The correlation coefficient of the detrended CORC VERT H2O MIX RATIO DET vertical gust/water vapor mixing ratio pair. CORC VERT CO2 MIX RATIO DET The correlation coefficient of the detrended vertical gust/carbon dioxide mixing ratio pair. CORC\_VERT\_O3\_CONC\_DET The correlation coefficient of the detrended vertical gust/ozone concentration pair. CORC VERT CH4 CONC DET The correlation coefficient of the detrended vertical gust/methane concentration pair. CORC\_POTNTL\_H2O\_MIX\_RATIO\_DET The correlation coefficient of the detrended potential temperature/water vapor mixing ratio MMNTM FLUX U WIND COMPNT DET The momentum flux using the detrended westerly wind component. MMNTM FLUX V WIND COMPNT DET The momentum flux using the detrended southerly wind component. MMNTM\_FLUX\_ALONG\_MEAN\_WIND\_DET The momentum flux using the detrended along mean wind component. MMNTM FLUX CROSS MEAN WIND DET The momentum flux using the detrended across mean wind component. SENSIBLE HEAT FLUX DET The detrended sensible heat flux. LATENT\_HEAT\_FLUX\_DET The detrended latent heat flux. CO2\_FLUX\_DET The detrended carbon dioxide flux. O3 FLUX DET The detrended ozone flux. O3 DEPOSITION VELOC DET The detrended ozone deposition velocity. CH4 FLUX DET The detrended methane flux. The BOREAS certification level of the data. CRTFCN\_CODE Examples are CPI (Checked by PI), CGR (Certified by Group), PRE (Preliminary), and CPI-??? (CPI but questionable). The most recent date when the information in the REVISION DATE referenced data base table record was revised.

#### 7.3.3 Unit of Measurement

The measurement units for the parameters contained in the data files on the CD-ROM are:

Column Name	Units
SPATIAL_COVERAGE	[none]
RUN_START_DATE	[DD-MON-YY]
RUN_START_TIME	[HHMMSS GMT]
RUN_END_DATE	[DD-MON-YY]
RUN_END_TIME	[HHMMSS GMT]
FLUX_MISSION_DESIGNATOR	[none]
FLUX_MISSION_NUM	[unitless]
FLUX_PASS_NUM	[unitless]
FLUX_SEGMENT_NUM	[unitless]
START_LATITUDE	[degrees]
START_LONGITUDE	[degrees]
END_LATITUDE	[degrees]
END_LONGITUDE	[degrees]
START_BOREAS_X	[kilometers]
START_BOREAS_Y	[kilometers]

```
END BOREAS X
                                [kilometers]
END_BOREAS_Y
                                [kilometers]
HEADING
                                [degrees]
MEAN PRESS ALTITUDE
                                [meters]
MEAN RADAR ALTITUDE
                                [meters]
MEAN_WIND_DIR
                                [degrees]
MEAN WIND SPEED
                                [meters][second^-1]
MEAN_AIR_TEMP
                                [degrees Celsius]
MEAN POTNTL TEMP
                                [degrees Kelvin]
MEAN H2O MIX RATIO
                                [grams of water vapor][kilogram dry air^-1]
MEAN U COMPNT WIND VELOC
                                [meters][second^-1]
MEAN V COMPNT WIND VELOC
                                [meters][second^-1]
MEAN_STATIC_PRESS
                                [kiloPascals]
                                [degrees Celsius]
MEAN SURF RAD TEMP
MEAN DOWN TOTAL RAD
                                [Watts][meter^-2]
MEAN UP TOTAL RAD
                                [Watts][meter^-2]
MEAN_DOWN_LONGWAVE_RAD
                                [Watts][meter^-2]
MEAN UP LONGWAVE RAD
                                [Watts][meter^-2]
MEAN_NET_RAD
                                [Watts][meter^-2]
MEAN UP PPFD
                                [microEinsteins][meter^-2][second^-1]
MEAN DOWN PPFD
                                [microEinsteins][meter^-2][second^-1]
MEAN AUX RAD
                                [Watts][meter^-2]
                                [unitless]
MEAN GREEN INDEX
                                [micromoles CO2][mole air^-1]
MEAN_CO2_CONC
MEAN 03 CONC
                                [nanomoles 03][mole air^-1]
MEAN CH4 CONC
                                [nanomoles CH4][mole air^-1]
MEAN SAT SIM CH1
                                [unitless]
MEAN_SAT_SIM_CH2
                                [unitless]
MEAN_SAT_SIM_CH3
                                [unitless]
MEAN SAT SIM CH4
                                [unitless]
SDEV AIR TEMP
                                [degrees Celsius]
SDEV POTNTL TEMP
                                [degrees Kelvin]
SDEV H2O MIX RATIO
                                [grams of water vapor][kilogram dry air^-1]
SDEV U COMPNT WIND VELOC
                                [meters][second^-1]
SDEV_V_COMPNT_WIND_VELOC
                                [meters][second^-1]
                                [kiloPascals]
SDEV STATIC PRESS
SDEV SURF RAD TEMP
                                [degrees Celsius]
SDEV DOWN TOTAL RAD
                                [Watts][meter^-2]
SDEV_UP_TOTAL_RAD
                                [Watts][meter^-2]
SDEV DOWN LONGWAVE RAD
                                [Watts][meter^-2]
SDEV_UP_LONGWAVE_RAD
                                [Watts][meter^-2]
SDEV NET RAD
                                [Watts][meter^-2]
SDEV UP PPFD
                                [microEinsteins][meter^-2][second^-1]
                                [microEinsteins][meter^-2][second^-1]
SDEV DOWN PPFD
SDEV_AUX_RAD
                                [unitless]
SDEV_GREEN_INDEX
                                [unitless]
                                [micromoles CO2][mole air^-1]
SDEV CO2 CONC
SDEV 03 CONC
                                [nanomoles 03][mole air^-1]
SDEV CH4 CONC
                                [nanomoles CH4][mole air^-1]
                                [unitless]
SDEV_SAT_SIM_CH1
SDEV_SAT_SIM_CH2
                                [unitless]
                                [unitless]
SDEV_SAT_SIM_CH3
SDEV SAT SIM CH4
                                [unitless]
TREND_AIR_TEMP
```

[degrees Celsius][meter^-1]

```
TREND POTNTL TEMP
                                [degrees Kelvin][meter^-1]
TREND_H2O_MIX_RATIO
                                [grams of water vapor][kilogram dry air^-1]
                                [meter^-1]
TREND U COMPNT WIND VELOC
                                [second^-1]
TREND V COMPNT WIND VELOC
                                [second^-1]
TREND_STATIC_PRESS
                                [kiloPascals][meter^-1]
TREND SURF RAD TEMP
                                [degrees Celsius][meter^-1]
TREND_DOWN_TOTAL_RAD
                                [Watts][meter^-3]
TREND UP TOTAL RAD
                                [Watts][meter^-3]
TREND DOWN LONGWAVE RAD
                                [Watts][meter^-3]
TREND UP LONGWAVE RAD
                                [Watts][meter^-3]
TREND GREEN INDEX
                                [meter^-1]
                                [micromoles CO2][mole air^-1][meter^-1]
TREND_CO2_CONC
                                [nanomoles 03][mole air^-1][meter^-1]
TREND 03 CONC
TREND CH4 CONC
                                [nanomoles CH4][mole air^-1][meter^-1]
SDEV VERT GUST RAW
                                [meters][second^-1]
SDEV_U_COMPNT_WIND_VELOC_RAW
                                [meters][second^-1]
SDEV_V_COMPNT_WIND_VELOC_RAW
                                [meters][second^-1]
                                [meters][second^-1]
SDEV_ALONG_WIND_RAW
SDEV CROSS WIND RAW
                                [meters][second^-1]
SDEV_POTNTL_TEMP_RAW
                                [degrees Kelvin]
SDEV_H2O_MIX_RATIO_RAW
                                [grams of water vapor][kilogram dry air^-1]
                                [unitless]
SDEV_CO2_MIX_RATIO_RAW
                                [nanomoles 03][mole air^-1]
SDEV_O3_CONC_RAW
                                [nanomoles CH4][mole air^-1]
SDEV CH4 CONC RAW
SKEW VERT GUST RAW
                                [meters][second^-1]
SKEW U COMPNT WIND VELOC RAW
                                [meters][second^-1]
SKEW_V_COMPNT_WIND_VELOC_RAW
                                [meters][second^-1]
SKEW ALONG WIND RAW
                                [meters][second^-1]
SKEW_CROSS_WIND_RAW
                                [meters][second^-1]
SKEW POTNTL TEMP RAW
                                [degrees Kelvin]
SKEW_H2O_MIX_RATIO_RAW
                                [grams of water vapor][kilogram dry air^-1]
SKEW CO2 MIX RATIO
                                [unitless]
                                [nanomoles 03][mole air^-1]
SKEW O3 CONC RAW
                                [nanomoles CH4][mole air^-1]
SKEW_CH4_CONC_RAW
KURT VERT GUST RAW
                                [meters][second^-1]
KURT U COMPNT WIND VELOC RAW
                                [meters][second^-1]
KURT V COMPNT WIND VELOC RAW
                                [meters][second^-1]
KURT_ALONG_WIND_RAW
                                [meters][second^-1]
KURT CROSS WIND RAW
                                [meters][second^-1]
                                [degrees Kelvin]
KURT_POTNTL_TEMP_RAW
KURT H2O MIX RATIO RAW
                                [grams of water vapor][kilogram dry air^-1]
KURT CO2 MIX RATIO RAW
                                [unitless]
KURT_O3_CONC_RAW
                                [nanomoles 03][mole air^-1]
KURT_CH4_CONC_RAW
                                [nanomoles CH4][mole air^-1]
CORC_VERT_U_WIND_COMPNT_RAW
                                [meters^2][second^-2]
CORC VERT V WIND COMPNT RAW
                                [meters^2][second^-2]
CORC_VERT_ALONG_WIND_RAW
                                [meters^2][second^-2]
CORC VERT CROSS WIND RAW
                                [meters^2][second^-2]
CORC_VERT_POTNTL_TEMP_RAW
                                [degrees Kelvin][meters][second^-1]
CORC_VERT_H2O_MIX_RATIO_RAW
                                [grams of water vapor][meters]
                                [kilogram dry air^ -1][second^-1]
CORC VERT CO2 MIX RATIO RAW
                                [unitless]
                                [nanomoles O3][meters][mole air^-1][second^-1]
CORC_VERT_O3_CONC_RAW
```

```
CORC_VERT_CH4_CONC_RAW
                                [nanomoles CH4][meters][mole air^-1][second^-1]
CORC_POTNTL_H2O_MIX_RATIO_RAW
                                [grams of water vapor][degrees Kelvin]
                                [kilogram dry air^-1]
MMNTM FLUX V WIND COMPNT RAW
                                [Newtons][meter^-2]
MMNTM FLUX U WIND COMPNT RAW
                                [Newtons][meter^-2]
MMNTM_FLUX_ALONG_MEAN_WIND_RAW [Newtons][meter^-2]
MMNTM FLUX CROSS MEAN WIND RAW [Newtons][meter^-2]
SENSIBLE_HEAT_FLUX_RAW
                                [Watts][meter^-2]
LATENT HEAT FLUX RAW
                                [Watts][meter^-2]
CO2 FLUX RAW
                                [micromoles CO2][meter^-2][second^-1]
O3 FLUX RAW
                                [nanomoles 03][meter^-2][second^-1]
O3_DEPOSITION_VELOC_RAW
                                [millimeters][second^-1]
CH4_FLUX_RAW
                                [nanomoles CH4][meter^-2][second^-1]
                                [kilograms][meter^-3]
AIR DENSITY CONSTANT
SPECIFIC HEAT CONSTANT
                                [Joules][kilogram^-1][degree Kelvin^-1]
LATENT HEAT VAP CONSTANT
                                [Joules][kilogram^-1]
DRY_AIR_GAS_CONSTANT
                                [Joules][kilogram^-1][degree Kelvin^-1]
SDEV VERT GUST DET
                                [meters][second^-1]
SDEV_U_COMPNT_WIND_VELOC_DET
                                [meters][second^-1]
SDEV V COMPNT WIND VELOC DET
                                [meters][second^-1]
                                [meters][second^-1]
SDEV_ALONG_WIND_DET
SDEV_CROSS_WIND_DET
                                [meters][second^-1]
                                [degrees Kelvin]
SDEV_POTNTL_TEMP_DET
SDEV_H2O_MIX_RATIO_DET
                                [grams of water vapor][kilogram dry air^-1]
SDEV CO2 MIX RATIO
                                [unitless]
SDEV 03 CONC DET
                                [nanomoles 03][mole air^-1]
SDEV CH4 CONC DET
                                [nanomoles CH4][mole air^-1]
                                [meters][second^-1]
SKEW_VERT_GUST_DET
SKEW_U_COMPNT_WIND_VELOC_DET
                                [meters][second^-1]
SKEW_V_COMPNT_WIND_VELOC_DET
                                [meters][second^-1]
SKEW ALONG WIND DET
                                [meters][second^-1]
SKEW CROSS WIND DET
                                [meters][second^-1]
SKEW_POTNTL_TEMP_DET
                                [degrees Kelvin]
                                [grams of water vapor][kilogram dry air^-1]
SKEW_H2O_MIX_RATIO_DET
SKEW_CO2_MIX_RATIO_DET
                                [unitless]
                                [nanomoles 03][mole air^-1]
SKEW O3 CONC DET
SKEW_CH4_CONC_DET
                                [nanomoles CH4][mole air^-1]
KURT VERT GUST DET
                                [meters][second^-1]
KURT_U_COMPNT_WIND_VELOC_DET
                                [meters][second^-1]
KURT_V_COMPNT_WIND_VELOC_DET
                                [meters][second^-1]
                                [meters][second^-1]
KURT_ALONG_WIND_DET
                                [meters][second^-1]
KURT CROSS WIND DET
KURT_POTNTL_TEMP_DET
                                [degrees Kelvin]
KURT_H2O_MIX_RATIO_DET
                                [grams of water vapor][kilogram dry air^-1]
KURT_CO2_MIX_RATIO_DET
                                [unitless]
KURT_O3_CONC_DET
                                [nanomoles O3][mole air^-1]
                                [nanomoles CH4][mole air^-1]
KURT CH4 CONC DET
CORC_VERT_U_WIND_COMPNT_DET
                                [meters^2][second^-2]
CORC VERT V WIND COMPNT DET
                                [meters^2][second^-2]
CORC_VERT_ALONG_WIND_DET
                                [meters^2][second^-2]
CORC_VERT_CROSS_WIND_DET
                                [meters^2][second^-2]
CORC_VERT_POTNTL_TEMP_DET
                                [degrees Kelvin][meters][second^-1]
                                [grams of water vapor][meters]
CORC_VERT_H2O_MIX_RATIO_DET
                                [kilogram dry air^ -1][second^-1]
```

```
CORC_VERT_CO2_MIX_RATIO_DET
                               [unitless]
                               [nanomoles 03][meters][mole air^-1][second^-1]
CORC_VERT_O3_CONC_DET
CORC VERT CH4 CONC DET
                               [nanomoles CH4][meters][mole air^-1][second^-1]
CORC_POTNTL_H2O_MIX_RATIO_DET
                               [grams of water vapor][degrees Kelvin]
                               [kilogram dry air^-1]
MMNTM_FLUX_U_WIND_COMPNT_DET
                               [Newtons][meter^-2]
                               [Newtons][meter^-2]
MMNTM_FLUX_V_WIND_COMPNT_DET
MMNTM_FLUX_ALONG_MEAN_WIND_DET [Newtons][meter^-2]
MMNTM FLUX CROSS MEAN WIND DET [Newtons][meter^-2]
SENSIBLE_HEAT_FLUX_DET
                               [Watts][meter^-2]
LATENT_HEAT_FLUX_DET
                               [Watts][meter^-2]
CO2_FLUX_DET
                               [micromoles CO2][meter^-2][second^-1]
                               [nanomoles 03][meter^-2][second^-1]
O3_FLUX_DET
O3 DEPOSITION VELOC DET
                               [millimeters][second^-1]
CH4 FLUX DET
                               [nanomoles CH4][meter^-2][second^-1]
CRTFCN CODE
                               [none]
                               [DD-MON-YY]
REVISION_DATE
```

### 7.3.4 Data Source

The sources of the parameter values contained in the data files on the CD-ROM are:

Column Name	Data Source
SPATIAL_COVERAGE	[Assigned by BORIS.]
RUN_START_DATE	[Supplied by AFM-04.]
RUN_START_TIME	[Supplied by AFM-04.]
RUN_END_DATE	[Supplied by AFM-04.]
RUN_END_TIME	[Supplied by AFM-04.]
FLUX_MISSION_DESIGNATOR	[Supplied by AFM-04.]
FLUX_MISSION_NUM	[Supplied by AFM-04.]
FLUX_PASS_NUM	[Supplied by AFM-04.]
FLUX_SEGMENT_NUM	[Supplied by AFM-04.]
START_LATITUDE	[Supplied by AFM-04.]
START_LONGITUDE	[Supplied by AFM-04.]
END_LATITUDE	[Supplied by AFM-04.]
END_LONGITUDE	[Supplied by AFM-04.]
START_BOREAS_X	[Supplied by AFM-04.]
START_BOREAS_Y	[Supplied by AFM-04.]
END_BOREAS_X	[Supplied by AFM-04.]
END_BOREAS_Y	[Supplied by AFM-04.]
HEADING	[Supplied by AFM-04.]
MEAN_PRESS_ALTITUDE	[Supplied by AFM-04.]
MEAN_RADAR_ALTITUDE	[Supplied by AFM-04.]
MEAN_WIND_DIR	[Supplied by AFM-04.]
MEAN_WIND_SPEED	[Supplied by AFM-04.]
MEAN_AIR_TEMP	[Supplied by AFM-04.]
MEAN_POTNTL_TEMP	[Supplied by AFM-04.]
MEAN_H2O_MIX_RATIO	[Supplied by AFM-04.]
MEAN_U_COMPNT_WIND_VELOC	[Supplied by AFM-04.]
MEAN_V_COMPNT_WIND_VELOC	[Supplied by AFM-04.]
MEAN_STATIC_PRESS	[Supplied by AFM-04.]
MEAN_SURF_RAD_TEMP	[Supplied by AFM-04.]
MEAN_DOWN_TOTAL_RAD	[Supplied by AFM-04.]
MEAN_UP_TOTAL_RAD	[Supplied by AFM-04.]

WELL BOING LONGWING DAD		4 7
MEAN_DOWN_LONGWAVE_RAD	[Supplied by AFM-04	
MEAN_UP_LONGWAVE_RAD	[Supplied by AFM-04	
MEAN_NET_RAD	[Supplied by AFM-04	
MEAN_UP_PPFD	[Supplied by AFM-04	
MEAN_DOWN_PPFD	[Supplied by AFM-04	
MEAN_AUX_RAD	[Supplied by AFM-04	
MEAN_GREEN_INDEX	[Supplied by AFM-04	
MEAN_CO2_CONC	[Supplied by AFM-04	
MEAN_O3_CONC	[Supplied by AFM-04	
MEAN_CH4_CONC	[Supplied by AFM-04	
MEAN_SAT_SIM_CH1	[Supplied by AFM-04	
MEAN_SAT_SIM_CH2	[Supplied by AFM-04	
MEAN_SAT_SIM_CH3	[Supplied by AFM-04	1.]
MEAN_SAT_SIM_CH4	[Supplied by AFM-04	1.]
SDEV_AIR_TEMP	[Supplied by AFM-04	1.]
SDEV_POTNTL_TEMP	[Supplied by AFM-04	1.]
SDEV_H2O_MIX_RATIO	[Supplied by AFM-04	1.]
SDEV_U_COMPNT_WIND_VELOC	[Supplied by AFM-04	1.]
SDEV_V_COMPNT_WIND_VELOC	[Supplied by AFM-04	1.]
SDEV_STATIC_PRESS	[Supplied by AFM-04	1.]
SDEV_SURF_RAD_TEMP	[Supplied by AFM-04	
SDEV_DOWN_TOTAL_RAD	[Supplied by AFM-04	
SDEV_UP_TOTAL_RAD	[Supplied by AFM-04	
SDEV_DOWN_LONGWAVE_RAD	[Supplied by AFM-04	
SDEV_UP_LONGWAVE_RAD	[Supplied by AFM-04	
SDEV_NET_RAD	[Supplied by AFM-04	
SDEV_UP_PPFD	[Supplied by AFM-04	
SDEV_DOWN_PPFD	[Supplied by AFM-04	
SDEV_AUX_RAD	[Supplied by AFM-04	
SDEV_GREEN_INDEX	[Supplied by AFM-04	
SDEV_CO2_CONC	[Supplied by AFM-04	
SDEV_03_CONC	[Supplied by AFM-04	
SDEV_CH4_CONC	[Supplied by AFM-04	
SDEV_SAT_SIM_CH1	[Supplied by AFM-04	
SDEV_SAT_SIM_CH2	[Supplied by AFM-04	
SDEV_SAT_SIM_CH2 SDEV_SAT_SIM_CH3	[Supplied by AFM-04	
	[Supplied by AFM-04	
SDEV_SAT_SIM_CH4		
TREND_AIR_TEMP	[Supplied by AFM-04	
TREND_POTNTL_TEMP	[Supplied by AFM-04	
TREND_H2O_MIX_RATIO	[Supplied by AFM-04	
TREND_U_COMPNT_WIND_VELOC	[Supplied by AFM-04	
TREND_V_COMPNT_WIND_VELOC	[Supplied by AFM-04	
TREND_STATIC_PRESS	[Supplied by AFM-04	
TREND_SURF_RAD_TEMP	[Supplied by AFM-04	
TREND_DOWN_TOTAL_RAD	[Supplied by AFM-04	
TREND_UP_TOTAL_RAD	[Supplied by AFM-04	
TREND_DOWN_LONGWAVE_RAD	[Supplied by AFM-04	
TREND_UP_LONGWAVE_RAD	[Supplied by AFM-04	
TREND_GREEN_INDEX	[Supplied by AFM-04	
TREND_CO2_CONC	[Supplied by AFM-04	
TREND_O3_CONC	[Supplied by AFM-04	1.]
TREND_CH4_CONC	[Supplied by AFM-04	1.]
SDEV_VERT_GUST_RAW	[Supplied by AFM-04	1.]
SDEV_U_COMPNT_WIND_VELOC_RAW	[Supplied by AFM-04	
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SDEV V COMPNT WIND VELOC RAW
                                [Supplied by AFM-04.]
SDEV_ALONG_WIND_RAW
                                [Supplied by AFM-04.]
                                [Supplied by AFM-04.]
SDEV CROSS WIND RAW
SDEV_POTNTL_TEMP_RAW
                                [Supplied by AFM-04.]
SDEV H2O MIX RATIO RAW
                                [Supplied by AFM-04.]
SDEV_CO2_MIX_RATIO_RAW
                                [Supplied by AFM-04.]
SDEV_O3_CONC_RAW
                                [Supplied by AFM-04.]
SDEV_CH4_CONC_RAW
                                [Supplied by AFM-04.]
SKEW VERT GUST RAW
                                [Supplied by AFM-04.]
SKEW U COMPNT WIND VELOC RAW
                                [Supplied by AFM-04.]
SKEW_V_COMPNT_WIND_VELOC_RAW
                                [Supplied by AFM-04.]
                                [Supplied by AFM-04.]
SKEW_ALONG_WIND_RAW
SKEW_CROSS_WIND_RAW
                                [Supplied by AFM-04.]
                                [Supplied by AFM-04.]
SKEW POTNTL TEMP RAW
SKEW_H2O_MIX_RATIO_RAW
                                [Supplied by AFM-04.]
SKEW CO2 MIX RATIO
                                [Supplied by AFM-04.]
SKEW_O3_CONC_RAW
                                [Supplied by AFM-04.]
SKEW CH4 CONC RAW
                                [Supplied by AFM-04.]
KURT_VERT_GUST_RAW
                                [Supplied by AFM-04.]
KURT U COMPNT WIND VELOC RAW
                                [Supplied by AFM-04.]
KURT V COMPNT WIND VELOC RAW
                                [Supplied by AFM-04.]
                                [Supplied by AFM-04.]
KURT_ALONG_WIND_RAW
                                [Supplied by AFM-04.]
KURT_CROSS_WIND_RAW
KURT_POTNTL_TEMP_RAW
                                [Supplied by AFM-04.]
KURT H2O MIX RATIO RAW
                                [Supplied by AFM-04.]
                                [Supplied by AFM-04.]
KURT_CO2_MIX_RATIO_RAW
KURT O3 CONC RAW
                                [Supplied by AFM-04.]
KURT_CH4_CONC_RAW
                                [Supplied by AFM-04.]
CORC_VERT_U_WIND_COMPNT_RAW
                                [Supplied by AFM-04.]
CORC_VERT_V_WIND_COMPNT_RAW
                                [Supplied by AFM-04.]
CORC VERT ALONG WIND RAW
                                [Supplied by AFM-04.]
CORC_VERT_CROSS_WIND_RAW
                                [Supplied by AFM-04.]
CORC_VERT_POTNTL_TEMP_RAW
                                [Supplied by AFM-04.]
                                [Supplied by AFM-04.]
CORC_VERT_H2O_MIX_RATIO_RAW
CORC_VERT_CO2_MIX_RATIO_RAW
                                [Supplied by AFM-04.]
CORC VERT O3 CONC RAW
                                [Supplied by AFM-04.]
CORC VERT CH4 CONC RAW
                                [Supplied by AFM-04.]
CORC POTNTL H2O MIX RATIO RAW
                                [Supplied by AFM-04.]
MMNTM_FLUX_V_WIND_COMPNT_RAW
                                [Supplied by AFM-04.]
MMNTM_FLUX_U_WIND_COMPNT_RAW
                                [Supplied by AFM-04.]
MMNTM_FLUX_ALONG_MEAN_WIND_RAW [Supplied by AFM-04.]
MMNTM FLUX CROSS MEAN WIND RAW [Supplied by AFM-04.]
                                [Supplied by AFM-04.]
SENSIBLE HEAT FLUX RAW
                                [Supplied by AFM-04.]
LATENT_HEAT_FLUX_RAW
CO2_FLUX_RAW
                                [Supplied by AFM-04.]
O3_FLUX_RAW
                                [Supplied by AFM-04.]
O3 DEPOSITION VELOC RAW
                                [Supplied by AFM-04.]
                                [Supplied by AFM-04.]
CH4_FLUX_RAW
AIR DENSITY CONSTANT
                                [Supplied by AFM-04.]
SPECIFIC_HEAT_CONSTANT
                                [Supplied by AFM-04.]
LATENT_HEAT_VAP_CONSTANT
                                [Supplied by AFM-04.]
DRY_AIR_GAS_CONSTANT
                                [Supplied by AFM-04.]
SDEV VERT GUST DET
                                [Supplied by AFM-04.]
SDEV_U_COMPNT_WIND_VELOC_DET
                                [Supplied by AFM-04.]
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SDEV V COMPNT WIND VELOC DET
                                [Supplied by AFM-04.]
SDEV_ALONG_WIND_DET
                                [Supplied by AFM-04.]
                                [Supplied by AFM-04.]
SDEV CROSS WIND DET
SDEV_POTNTL_TEMP_DET
                                [Supplied by AFM-04.]
SDEV H2O MIX RATIO DET
                                [Supplied by AFM-04.]
SDEV_CO2_MIX_RATIO
                                [Supplied by AFM-04.]
SDEV_O3_CONC_DET
                                [Supplied by AFM-04.]
                                [Supplied by AFM-04.]
SDEV_CH4_CONC_DET
SKEW VERT GUST DET
                                [Supplied by AFM-04.]
SKEW_U_COMPNT_WIND_VELOC_DET
                                [Supplied by AFM-04.]
SKEW_V_COMPNT_WIND_VELOC_DET
                                [Supplied by AFM-04.]
                                [Supplied by AFM-04.]
SKEW_ALONG_WIND_DET
SKEW_CROSS_WIND_DET
                                [Supplied by AFM-04.]
                                [Supplied by AFM-04.]
SKEW POTNTL TEMP DET
SKEW_H2O_MIX_RATIO_DET
                                [Supplied by AFM-04.]
SKEW CO2 MIX RATIO DET
                                [Supplied by AFM-04.]
SKEW_O3_CONC_DET
                                [Supplied by AFM-04.]
SKEW CH4 CONC DET
                                [Supplied by AFM-04.]
                                [Supplied by AFM-04.]
KURT_VERT_GUST_DET
KURT U COMPNT WIND VELOC DET
                                [Supplied by AFM-04.]
KURT V COMPNT WIND VELOC DET
                                [Supplied by AFM-04.]
KURT_ALONG_WIND_DET
                                [Supplied by AFM-04.]
                                [Supplied by AFM-04.]
KURT_CROSS_WIND_DET
KURT_POTNTL_TEMP_DET
                                [Supplied by AFM-04.]
KURT H2O MIX RATIO DET
                                [Supplied by AFM-04.]
                                [Supplied by AFM-04.]
KURT_CO2_MIX_RATIO_DET
KURT O3 CONC DET
                                [Supplied by AFM-04.]
KURT_CH4_CONC_DET
                                [Supplied by AFM-04.]
CORC_VERT_U_WIND_COMPNT_DET
                                [Supplied by AFM-04.]
CORC VERT V WIND COMPNT DET
                                [Supplied by AFM-04.]
CORC VERT ALONG WIND DET
                                [Supplied by AFM-04.]
                                [Supplied by AFM-04.]
CORC_VERT_CROSS_WIND_DET
CORC_VERT_POTNTL_TEMP_DET
                                [Supplied by AFM-04.]
                                [Supplied by AFM-04.]
CORC_VERT_H2O_MIX_RATIO_DET
CORC_VERT_CO2_MIX_RATIO_DET
                                [Supplied by AFM-04.]
                                [Supplied by AFM-04.]
CORC VERT O3 CONC DET
CORC_VERT_CH4_CONC_DET
                                [Supplied by AFM-04.]
CORC POTNTL H2O MIX RATIO DET
                                [Supplied by AFM-04.]
MMNTM_FLUX_U_WIND_COMPNT_DET
                                [Supplied by AFM-04.]
MMNTM_FLUX_V_WIND_COMPNT_DET
                                [Supplied by AFM-04.]
MMNTM_FLUX_ALONG_MEAN_WIND_DET [Supplied by AFM-04.]
MMNTM FLUX CROSS MEAN WIND DET [Supplied by AFM-04.]
                                [Supplied by AFM-04.]
SENSIBLE_HEAT_FLUX_DET
LATENT_HEAT_FLUX_DET
                                [Supplied by AFM-04.]
CO2_FLUX_DET
                                [Supplied by AFM-04.]
O3_FLUX_DET
                                [Supplied by AFM-04.]
O3 DEPOSITION VELOC DET
                                [Supplied by AFM-04.]
                                [Supplied by AFM-04.]
CH4_FLUX_DET
CRTFCN CODE
                                [Assigned by BORIS.]
REVISION_DATE
                                [Assigned by BORIS.]
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**7.3.5 Data Range**The following table gives information about the parameter values found in the data files on the CD-ROM.

	Minimum	Maximum	Missng			Data
Calumn Nama	Data	Data	Data	Data	Detect	Not
Column Name	Value 	Value	value	value	Limit	Cllctd
SPATIAL_COVERAGE	N/A	N/A	None	None	None	None
RUN_START_DATE	25-MAY-94	08-AUG-96	None	None	None	None
RUN_START_TIME	144728	225641	None	None	None	None
RUN_END_DATE	25-MAY-94	08-AUG-96	None	None	None	None
RUN_END_TIME	145137	230220	None	None	None	None
FLUX_MISSION_	AG	TS	None	None	None	None
DESIGNATOR						
FLUX_MISSION_NUM	1	8	None	None	None	None
FLUX_PASS_NUM	1	18	None	None	None	None
FLUX_SEGMENT_NUM	0	9	None	None	None	None
START_LATITUDE	53.332	55.94959	-999	None	None	None
START_LONGITUDE	-106.398	-97.99917	-999	None	None	None
END_LATITUDE	53.33467	55.96583	-999	None	None	None
END_LONGITUDE	-106.4038	-97.99467	-999	None	None	None
START_BOREAS_X	304.372	807.724	-999	None	None	None
START_BOREAS_Y	273.935	621.895	-999	None	None	None
END_BOREAS_X	86.463	808.028	-999	None	None	None
END_BOREAS_Y	274.246	9524.933	-999	None	None	None
HEADING	.1	359.8	None	None	None	None
MEAN_PRESS_ALTITUDE	261.5	2621.8	None	None	None	None
MEAN_RADAR_ALTITUDE	0	800.4	-999	None	None	None
MEAN_WIND_DIR	0	359.9	None	None	None	None
MEAN_WIND_SPEED	.06	11.32	None	None	None	None
MEAN_AIR_TEMP	67	28.4	None	None	None	None
MEAN_POTNTL_TEMP	283.13	307.47	None	None	None	None
MEAN_H2O_MIX_RATIO	.68	12.33	None	None	None	None
MEAN_U_COMPNT_WIND_	-7.74	9.55	None	None	None	None
VELOC						
MEAN_V_COMPNT_WIND_	-7.8	9.49	None	None	None	None
VELOC	F0 F2	00 16	3.7			3.7
MEAN_STATIC_PRESS	72.73	99.16	None	None	None	None
MEAN_SURF_RAD_TEMP	7.9	36.7	None	None	None	None
MEAN_DOWN_TOTAL_RAD	151.7	1301.3	None	None	None	None
MEAN_UP_TOTAL_RAD	14.1	173.3	None	None	None	None
MEAN_DOWN_LONGWAVE_			-999	None	None	None
RAD			0.00	Mono	None	None
MEAN_UP_LONGWAVE_RAD		071 F	-999 000	None	None	None
MEAN_NET_RAD	59.9	871.5	-999 000	None	None	None
MEAN_UP_PPFD			-999 000	None	None	None
MEAN_DOWN_PPFD			-999	None	None	None
MEAN_AUX_RAD	ГИ	4 00	-999 Nana	None	None	None
MEAN_GREEN_INDEX	.54	4.89	None	None	None	None
MEAN_CO2_CONC	338.3	385.9	None	None	None	None
MEAN_O3_CONC	-6.09	63.54	None	None	None	None
MEAN_CH4_CONC	0	10 00	-999 Nana	None	None	None
MEAN_SAT_SIM_CH1	0	10.89	None	None	None	None

MEAN_SAT_SIM_CH2	01	13.03	None	None	None	None
MEAN_SAT_SIM_CH3	03	26.65	None	None	None	None
MEAN_SAT_SIM_CH4	0	52.72	None	None	None	None
SDEV_AIR_TEMP	.04	1.22	None	None	None	None
SDEV_POTNTL_TEMP	.04	1.3	None	None	None	None
SDEV_H2O_MIX_RATIO	.02	1.07	None	None	None	None
SDEV_U_COMPNT_WIND_	.1	4.41	None	None	None	None
VELOC						
SDEV_V_COMPNT_WIND_	.1	3.58	None	None	None	None
VELOC						
SDEV_STATIC_PRESS	.01	.51	None	None	None	None
SDEV_SURF_RAD_TEMP	.21	8.23	None	None	None	None
SDEV_DOWN_TOTAL_RAD	2.1	798.9	-999	None	None	None
SDEV_UP_TOTAL_RAD	.2	57.1	None	None	None	None
SDEV_DOWN_LONGWAVE_			-999	None	None	None
RAD						
SDEV_UP_LONGWAVE_RAD			-999	None	None	None
SDEV NET RAD	3.4	793.4	-999	None	None	None
SDEV_UP_PPFD	3.1	,,,,,,	-999	None	None	None
SDEV DOWN PPFD			-999	None	None	None
SDEV_BOWN_ITTB			-999	None	None	None
SDEV_AGK_NAD SDEV GREEN INDEX	.01	1.22	None	None	None	None
SDEV_GREEN_INDEX SDEV CO2 CONC	.2	6.2		None	None	None
			None			
SDEV_O3_CONC	.05	26.22	None	None	None	None
SDEV_CH4_CONC	0	10 74	-999	None	None	None
SDEV_SAT_SIM_CH1	0	10.74	None	None	None	None
SDEV_SAT_SIM_CH2	0	10.94	None	None	None	None
SDEV_SAT_SIM_CH3	0	10.64	None	None	None	None
SDEV_SAT_SIM_CH4	0	21.67	None	None	None	None
TREND_AIR_TEMP	000572	.000797	None	None	None	None
TREND_POTNTL_TEMP	000569	.000835	None	None	None	None
TREND_H2O_MIX_RATIO	000634	.000417	None	None	None	None
TREND_U_COMPNT_WIND_	00229	.00388	None	None	None	None
VELOC						
TREND_V_COMPNT_WIND_	00237	.00191	None	None	None	None
VELOC						
TREND_STATIC_PRESS	000253	.000702	None	None	None	None
TREND_SURF_RAD_TEMP	00582	.00692	None	None	None	None
TREND_DOWN_TOTAL_RAD	332	.333	None	None	None	None
TREND_UP_TOTAL_RAD	0389	.0383	None	None	None	None
TREND_DOWN_LONGWAVE_			-999	None	None	None
RAD						
TREND_UP_LONGWAVE_			-999	None	None	None
RAD						
TREND GREEN INDEX	000699	.000576	None	None	None	None
TREND_CO2_CONC	00103	.00109	None	None	None	None
TREND_O3_CONC	0121	.0204	None	None	None	None
TREND CH4 CONC	. 0 - 1 - 1	.0201	-999	None	None	None
SDEV_VERT_GUST_RAW	.04	2.4	None	None	None	None
SDEV_U_COMPNT_WIND_	.1	4.41	None	None	None	None
VELOC_RAW	• ±	-· -	110110	11011	140110	110116
SDEV_V_COMPNT_WIND_	.1	3.58	None	None	None	None
		5.50	MOTTE	MOHE	MOHE	MOTTE
VELOC_RAW	ΛΩ	2 02	Nono	None	None	None
SDEV_ALONG_WIND_RAW	.08	3.82	None	None	None	None

SDEV_CROSS_WIND_RAW	.13	2.9	None	None	None	None
SDEV_POTNTL_TEMP_RAW	.04	1.3	None	None	None	None
SDEV_H2O_MIX_RATIO_	.02	1.07	None	None	None	None
RAW						
SDEV_CO2_MIX_RATIO_	. 2	6.2	None	None	None	None
RAW						
SDEV_O3_CONC_RAW	0	9.32	None	None	None	None
SDEV CH4 CONC RAW			-999	None	None	None
SKEW VERT GUST RAW			-999	None	None	None
SKEW_U_COMPNT_WIND_			-999	None	None	None
VELOC RAW						
SKEW_V_COMPNT_WIND_			-999	None	None	None
VELOC RAW						
SKEW ALONG WIND RAW			-999	None	None	None
SKEW CROSS WIND RAW			-999	None	None	None
SKEW POTNTL TEMP RAW			-999	None	None	None
SKEW H20 MIX RATIO			-999	None	None	None
RAW				NOTIC	NOTIC	NOTIC
SKEW CO2 MIX RATIO			-999	None	None	None
SKEW_COZ_MIX_RATIO			-999 -999	None	None	None
			-999 -999			
SKEW_CH4_CONC_RAW				None	None	None
KURT_VERT_GUST_RAW			-999	None	None	None
KURT_U_COMPNT_WIND_			-999	None	None	None
VELOC_RAW			000			
KURT_V_COMPNT_WIND_			-999	None	None	None
VELOC_RAW						
KURT_ALONG_WIND_RAW			-999	None	None	None
KURT_CROSS_WIND_RAW			-999	None	None	None
KURT_POTNTL_TEMP_RAW			-999	None	None	None
KURT_H2O_MIX_RATIO_			-999	None	None	None
RAW						
KURT_CO2_MIX_RATIO_			-999	None	None	None
RAW						
KURT_O3_CONC_RAW			-999	None	None	None
KURT_CH4_CONC_RAW			-999	None	None	None
CORC_VERT_U_WIND_	6	.87	None	None	None	None
COMPNT_RAW						
CORC_VERT_V_WIND_	73	.62	None	None	None	None
COMPNT_RAW						
CORC_VERT_ALONG_WIND	86	.6	None	None	None	None
RAW						
CORC_VERT_CROSS_WIND	84	.59	None	None	None	None
RAW						
CORC_VERT_POTNTL_	75	.8	None	None	None	None
TEMP_RAW						
CORC_VERT_H2O_MIX_	68	.76	None	None	None	None
RATIO_RAW						
CORC_VERT_CO2_MIX_	63	.58	None	None	None	None
RATIO_RAW	.03	.50	110110	1,0110	110110	110110
CORC_VERT_O3_CONC_	61	1.88	None	None	None	None
RAW	• • •		1,0110	1,0110	1,0110	1,0110
CORC_VERT_CH4_CONC_			-999	None	None	None
RAW				110116	11011	TAOTIC
	<b>-</b> 7 57	11.16	-999	None	None	None
CORC_POTNTL_H2O_MIX_	1.51	TT.TO	ーッフフ	MOHE	MOHE	MOHE

RATIO_RAW MMNTM FLUX V WIND	-1.3857	10	None	None	None	None
COMPNT RAW	-1.3037	10	None	None	None	None
MMNTM FLUX U WIND	-3.5566	1.4309	None	None	None	None
COMPNT RAW	-3.5500	1.4309	None	None	None	None
MMNTM FLUX ALONG	-3.1398	.447	None	None	None	None
	-3.1390	.44/	None	None	None	None
MEAN_WIND_RAW	-2.6673	1.203	None	None	None	Mono
MMNTM_FLUX_CROSS_	-2.00/3	1.203	None	None	None	None
MEAN_WIND_RAW	-122.4	489.5	None	None	None	Mono
SENSIBLE_HEAT_FLUX_ RAW	-122.4	409.5	None	None	None	None
	252 6	755	None	None	None	None
LATENT_HEAT_FLUX_RAW	-353.6	10.188		None	None	None
CO2_FLUX_RAW			None	None	None	None
O3_FLUX_RAW	-35.735	46.179	-999 000	None	None	None
O3_DEPOSITION_VELOC_	-28.3	45.5	-999	None	None	None
RAW CH4 FLUX RAW			-999	None	None	Mono
	002	11		None	None	None
AIR_DENSITY_CONSTANT			None	None	None	None
SPECIFIC_HEAT_	240	240	None	None	None	None
CONSTANT	2424	2502	Mono	Mana	Mana	Mara
LATENT_HEAT_VAP_	2434	2503	None	None	None	None
CONSTANT	2 07	0.07	Mono	Mana	Mana	Mara
DRY_AIR_GAS_CONSTANT		2.87	None	None	None	None
SDEV_VERT_GUST_DET	.03	12	None	None	None	None
SDEV_U_COMPNT_WIND_	.05	3.8	None	None	None	None
VELOC_DET	0.0	2 16	NT	NT	NT	37
SDEV_V_COMPNT_WIND_	.08	3.16	None	None	None	None
VELOC_DET	0.6	2 75	NT	NT	NT	37
SDEV_ALONG_WIND_DET	.06	3.75	None	None	None	None
SDEV_CROSS_WIND_DET	.1	2.57	None	None	None	None
SDEV_POTNTL_TEMP_DET		1.26	None	None	None	None
SDEV_H2O_MIX_RATIO_	.02	.95	None	None	None	None
DET	0	F (	NT	NT	NT	37
SDEV_CO2_MIX_RATIO	. 2	5.6	None	None	None	None
SDEV_O3_CONC_DET	0	9.32	None	None	None	None
SDEV_CH4_CONC_DET	1 60	1.2	-999 N	None	None	None
SKEW_VERT_GUST_DET	-1.69	13	None	None	None	None
SKEW_U_COMPNT_WIND_	-1./4	3.57	None	None	None	None
VELOC_DET	11 24	2 02	NT	NT	NT	NT
SKEW_V_COMPNT_WIND_	-11.34	2.03	None	None	None	None
VELOC_DET			0.00	NT	NT	37
SKEW_ALONG_WIND_DET			-999	None	None	None
SKEW_CROSS_WIND_DET	2 2	4 1 7	-999	None	None	None
SKEW_POTNTL_TEMP_DET		4.17	None	None	None	None
SKEW_H2O_MIX_RATIO_	-1.92	2.38	None	None	None	None
DET	F F4	15 5			3.7	
SKEW_CO2_MIX_RATIO_	-5.54	15.7	None	None	None	None
DET	4 56	0.06			3.7	
SKEW_O3_CONC_DET	-4.56	2.06	None	None	None	None
SKEW_CH4_CONC_DET	1 00	FF F0	-999 N	None	None	None
KURT_VERT_GUST_DET	1.99	55.59	None	None	None	None
KURT_U_COMPNT_WIND_	1.73	54.94	None	None	None	None
VELOC_DET	1 00	10.00	0.00	3.7	3.7	
KURT_V_COMPNT_WIND_	1.89	18.02	-999	None	None	None

VELOC DET						
KURT ALONG WIND DET			-999	None	None	None
KURT CROSS WIND DET			-999 -999	None	None	None
	1 02	21 52				
KURT_POTNTL_TEMP_DET		31.52	None	None	None	None
KURT_H2O_MIX_RATIO_ DET	1.44	14.48	None	None	None	None
KURT_CO2_MIX_RATIO_ DET	1.74	95.04	None	None	None	None
KURT O3 CONC DET	0	34.58	None	None	None	None
	U	34.30	-999			None
KURT_CH4_CONC_DET	<i>C</i> 1	1 5		None	None	
CORC_VERT_U_WIND_ COMPNT_DET	64	15	None	None	None	None
CORC_VERT_V_WIND_	73	.63	None	None	None	None
COMPNT_DET						
CORC_VERT_ALONG_WIND	71	.52	None	None	None	None
CORC VERT CROSS WIND	_ 74	.58	None	None	None	None
DET	_ •/=	. 50	NOHE	NOTIC	NOTIC	NOME
CORC_VERT_POTNTL_	67	.8	None	None	None	None
TEMP DET	.07	.0	NOTIE	NOTIC	NOHE	NOME
CORC_VERT_H2O_MIX_	68	.74	None	None	None	None
	00	. / 4	None	None	None	None
RATIO_DET	67	4.2	NT	NT	<b>N</b> T	NT
CORC_VERT_CO2_MIX_	67	.43	None	None	None	None
RATIO_DET	<b>5</b> 0	1 00				
CORC_VERT_O3_CONC_	59	1.88	None	None	None	None
DET						
CORC_VERT_CH4_CONC_			-999	None	None	None
DET						
CORC_POTNTL_H2O_MIX_	93	.9	None	None	None	None
RATIO_DET						
MMNTM_FLUX_U_WIND_	-1.5758	16	None	None	None	None
COMPNT_DET						
MMNTM_FLUX_V_WIND_	-3.4116	1.3096	None	None	None	None
COMPNT_DET						
MMNTM_FLUX_ALONG_	-2.9921	.3646	None	None	None	None
MEAN_WIND_DET						
MMNTM_FLUX_CROSS_	-2.6699	1.211	None	None	None	None
MEAN_WIND_DET						
SENSIBLE_HEAT_FLUX_	-54.9	490.2	None	None	None	None
DET						
LATENT_HEAT_FLUX_DET	-269.6	557.5	None	None	None	None
CO2 FLUX DET	-26.219	10.796	None	None	None	None
O3_FLUX_DET	-22.952	44.792	-999	None	None	None
O3_DEPOSITION_VELOC_		32.3	-999	None	None	None
DET	-27.3	32.3	-999	None	None	None
CH4_FLUX_DET			-999	None	None	None
CRTFCN_CODE	CPI	CPI	None	None	None	None
REVISION_DATE	12-AUG-96	25-JUN-99	None	None	None	None

Minimum Data Value  $\operatorname{--}$  The minimum value found in the column. Maximum Data Value  $\operatorname{--}$  The maximum value found in the column.

Missng Data Value -- The value that indicates missing data. This is used to indicate that an attempt was made to determine the parameter value, but the attempt was unsuccessful.

Unrel Data Value -- The value that indicates unreliable data. This is used to indicate an attempt was made to determine the parameter value, but the value was deemed to be unreliable by the analysis personnel.

Below Detect Limit -- The value that indicates parameter values below the instruments detection limits. This is used to indicate that an attempt was made to determine the parameter value, but the analysis personnel determined that the parameter value was below the detection limit of the instrumentation.

Data Not Cllctd -- This value indicates that no attempt was made to determine the parameter value. This usually indicates that BORIS combined several similar but not identical data sets into the same data base table but this particular science team did not measure that parameter.

Blank -- Indicates that blank spaces are used to denote that type of value. N/A -- Indicates that the value is not applicable to the respective column. None -- Indicates that no values of that sort were found in the column.

## 7.4 Sample Data Record

The following are wrapped versions of data record from a sample data file on the CD-ROM.

SPATIAL COVERAGE, RUN START DATE, RUN START TIME, RUN END DATE, RUN END TIME, FLUX\_MISSION\_DESIGNATOR,FLUX\_MISSION\_NUM,FLUX\_PASS\_NUM,FLUX\_SEGMENT\_NUM, START\_LATITUDE, START\_LONGITUDE, END\_LATITUDE, END\_LONGITUDE, START\_BOREAS\_X, START\_BOREAS\_Y, END\_BOREAS\_X, END\_BOREAS\_Y, HEADING, MEAN\_PRESS\_ALTITUDE, MEAN RADAR ALTITUDE, MEAN WIND DIR, MEAN WIND SPEED, MEAN AIR TEMP, MEAN\_POTNTL\_TEMP, MEAN\_H2O\_MIX\_RATIO, MEAN\_U\_COMPNT\_WIND\_VELOC, MEAN\_V\_COMPNT\_WIND\_VELOC, MEAN\_STATIC\_PRESS, MEAN\_SURF\_RAD\_TEMP, MEAN\_DOWN\_TOTAL\_RAD, MEAN\_UP\_TOTAL\_RAD, MEAN\_DOWN\_LONGWAVE\_RAD, MEAN\_UP\_LONGWAVE\_RAD, MEAN\_NET\_RAD, MEAN\_UP\_PPFD, MEAN\_DOWN\_PPFD, MEAN\_AUX\_RAD, MEAN GREEN INDEX, MEAN CO2 CONC, MEAN O3 CONC, MEAN CH4 CONC, MEAN SAT SIM CH1, MEAN\_SAT\_SIM\_CH2, MEAN\_SAT\_SIM\_CH3, MEAN\_SAT\_SIM\_CH4, SDEV\_AIR\_TEMP, SDEV POTNTL TEMP, SDEV H2O MIX RATIO, SDEV U COMPNT WIND VELOC, SDEV\_V\_COMPNT\_WIND\_VELOC, SDEV\_STATIC\_PRESS, SDEV\_SURF\_RAD\_TEMP, SDEV\_DOWN\_TOTAL\_RAD, SDEV\_UP\_TOTAL\_RAD, SDEV\_DOWN\_LONGWAVE\_RAD, SDEV\_UP\_LONGWAVE\_RAD, SDEV\_NET\_RAD, SDEV\_UP\_PPFD, SDEV\_DOWN\_PPFD, SDEV\_AUX\_RAD, SDEV GREEN INDEX, SDEV CO2 CONC, SDEV O3 CONC, SDEV CH4 CONC, SDEV SAT SIM CH1, SDEV\_SAT\_SIM\_CH2,SDEV\_SAT\_SIM\_CH3,SDEV\_SAT\_SIM\_CH4,TREND\_AIR\_TEMP, TREND\_POTNTL\_TEMP, TREND\_H2O\_MIX\_RATIO, TREND\_U\_COMPNT\_WIND\_VELOC, TREND\_V\_COMPNT\_WIND\_VELOC,TREND\_STATIC\_PRESS,TREND\_SURF\_RAD\_TEMP, TREND\_DOWN\_TOTAL\_RAD, TREND\_UP\_TOTAL\_RAD, TREND\_DOWN\_LONGWAVE\_RAD, TREND UP LONGWAVE RAD, TREND GREEN INDEX, TREND CO2 CONC, TREND O3 CONC, TREND\_CH4\_CONC, SDEV\_VERT\_GUST\_RAW, SDEV\_U\_COMPNT\_WIND\_VELOC\_RAW, SDEV V COMPNT WIND VELOC RAW, SDEV ALONG WIND RAW, SDEV CROSS WIND RAW, SDEV\_POTNTL\_TEMP\_RAW, SDEV\_H2O\_MIX\_RATIO\_RAW, SDEV\_CO2\_MIX\_RATIO\_RAW, SDEV\_O3\_CONC\_RAW, SDEV\_CH4\_CONC\_RAW, SKEW\_VERT\_GUST\_RAW, SKEW\_U\_COMPNT\_WIND\_VELOC\_RAW, SKEW\_V\_COMPNT\_WIND\_VELOC\_RAW, SKEW\_ALONG\_WIND\_RAW, SKEW CROSS WIND RAW, SKEW POTNTL TEMP RAW, SKEW H2O MIX RATIO RAW, SKEW\_CO2\_MIX\_RATIO,SKEW\_O3\_CONC\_RAW,SKEW\_CH4\_CONC\_RAW,KURT\_VERT\_GUST\_RAW,

```
KURT_U_COMPNT_WIND_VELOC_RAW, KURT_V_COMPNT_WIND_VELOC_RAW, KURT_ALONG_WIND_RAW,
KURT_CROSS_WIND_RAW, KURT_POTNTL_TEMP_RAW, KURT_H2O_MIX_RATIO_RAW,
KURT CO2 MIX RATIO RAW, KURT O3 CONC RAW, KURT CH4 CONC RAW,
CORC_VERT_U_WIND_COMPNT_RAW, CORC_VERT_V_WIND_COMPNT_RAW,
CORC VERT ALONG WIND RAW, CORC VERT CROSS WIND RAW, CORC VERT POTNTL TEMP RAW,
CORC_VERT_H2O_MIX_RATIO_RAW, CORC_VERT_CO2_MIX_RATIO_RAW, CORC_VERT_O3_CONC_RAW,
CORC_VERT_CH4_CONC_RAW, CORC_POTNTL_H2O_MIX_RATIO_RAW,
MMNTM_FLUX_V_WIND_COMPNT_RAW, MMNTM_FLUX_U_WIND_COMPNT_RAW,
MMNTM FLUX ALONG MEAN WIND RAW, MMNTM FLUX CROSS MEAN WIND RAW,
SENSIBLE HEAT FLUX RAW, LATENT HEAT FLUX RAW, CO2 FLUX RAW, O3 FLUX RAW,
O3_DEPOSITION_VELOC_RAW, CH4_FLUX_RAW, AIR_DENSITY_CONSTANT,
SPECIFIC_HEAT_CONSTANT, LATENT_HEAT_VAP_CONSTANT, DRY_AIR_GAS_CONSTANT,
SDEV_VERT_GUST_DET,SDEV_U_COMPNT_WIND_VELOC_DET,SDEV_V_COMPNT_WIND_VELOC_DET,
SDEV ALONG WIND DET, SDEV CROSS WIND DET, SDEV POTNTL TEMP DET,
SDEV H20 MIX RATIO DET, SDEV CO2 MIX RATIO, SDEV O3 CONC DET, SDEV CH4 CONC DET,
SKEW VERT GUST DET, SKEW U COMPNT WIND VELOC DET, SKEW V COMPNT WIND VELOC DET,
SKEW_ALONG_WIND_DET,SKEW_CROSS_WIND_DET,SKEW_POTNTL_TEMP_DET,
SKEW_H2O_MIX_RATIO_DET, SKEW_CO2_MIX_RATIO_DET, SKEW_O3_CONC_DET,
SKEW_CH4_CONC_DET, KURT_VERT_GUST_DET, KURT_U_COMPNT_WIND_VELOC_DET,
KURT V COMPNT WIND VELOC DET, KURT ALONG WIND DET, KURT CROSS WIND DET,
KURT POTNTL TEMP DET, KURT H2O MIX RATIO DET, KURT CO2 MIX RATIO DET,
KURT_O3_CONC_DET, KURT_CH4_CONC_DET, CORC_VERT_U_WIND_COMPNT_DET,
CORC_VERT_V_WIND_COMPNT_DET,CORC_VERT_ALONG_WIND_DET,CORC_VERT_CROSS_WIND_DET,
CORC_VERT_POTNTL_TEMP_DET, CORC_VERT_H2O_MIX_RATIO_DET,
CORC VERT CO2 MIX RATIO DET, CORC VERT O3 CONC DET, CORC VERT CH4 CONC DET,
CORC_POTNTL_H2O_MIX_RATIO_DET,MMNTM_FLUX_U_WIND_COMPNT_DET,
MMNTM FLUX V WIND COMPNT DET, MMNTM FLUX ALONG MEAN WIND DET,
MMNTM_FLUX_CROSS_MEAN_WIND_DET,SENSIBLE_HEAT_FLUX_DET,LATENT_HEAT_FLUX_DET,
CO2_FLUX_DET,O3_FLUX_DET,O3_DEPOSITION_VELOC_DET,CH4_FLUX_DET,CRTFCN_CODE,
REVISION_DATE
'SSA', 26-MAY-94, 161101, 26-MAY-94, 161639, 'AG', 1, 1, 0, 53.332, -105.4838, 53.51317,
-105.4832,366.884,273.935,365.327,294.052,358.2,505.5,30.1,194.4,7.73,19.49,
296.74,6.2,1.92,7.49,95.27,22.0,691.3,109.9,-999.0,-999.0,487.7,-999.0,-999.0,
-999.0, 1.26, 368.6, 32.72, -999.0, 8.17, 10.41, 11.49, 22.95, .26, .24, .2, 1.33, 1.34, .11,
2.9, 26.4, 23.7, -999.0, -999.0, 38.6, -999.0, -999.0, -999.0, .37, 1.3, 1.39, -999.0, 3.18,
4.5, 4.25, 7.55, -.0000216, -.0000162, .00000693, -.000113, -.00000226, -.00000639,
-.000058,.00136,.000382,-999.0,-999.0,-.0000208,.000201,.000114,-999.0,.66,
1.33,1.34,1.38,1.29,.24,.2,1.3,.78,-999.0,-999.0,-999.0,-999.0,-999.0,-999.0,
-999.0,-999.0,-999.0,-999.0,-999.0,-999.0,-999.0,-999.0,-999.0,-999.0,-999.0,
-999.0, -999.0, -999.0, -999.0, -.06, -.22, -.22, 0.0, .41, .43, .07, -.28, -999.0, .4, \\
-.0552, -.2169, -.2238, -.0003, 73.0, 156.0, 2.432, -5.722, 4.5, -999.0, 1.134, 240.0,
2455,2.87,.66,1.16,1.34,1.37,1.13,.22,.2,.6,.68,-999.0,.23,-.16,-.4,-999.0,
-999.0, .75, .61, -.08, -.15, -999.0, 3.3, 3.05, 3.32, -999.0, -999.0, 3.35, 4.72, 3.02,
3.43,-999.0,-.06,-.22,-.22,0.0,.45,.44,.18,-.32,-999.0,.58,-.0543,-.2169,
-.2236,-.0012,73.1,156.3,2.575,-5.708,4.5,-999.0,'CPI',12-AUG-96
```

## 8. Data Organization

#### 8.1 Data Granularity

The smallest orderable data set available is one file of flux runs during a day for a given study area. Note that although there are fewer than 100 records in any data file, there are over 170 columns of data. Most spreadsheet software should be able to handle up to 256 columns of data.

#### 8.2 Data Format(s)

The Compact Disk-Read-Only Memory (CD-ROM) files contain ASCII numerical and character fields of varying length separated by commas. The character fields are enclosed with single apostrophe marks. There are no spaces between the fields.

Each data file on the CD-ROM has four header lines of Hyper-Text Markup Language (HTML) code at the top. When viewed with a Web browser, this code displays header information (data set title, location, date, acknowledgments, etc.) and a series of HTML links to associated data files and related data sets. Line 5 of each data file is a list of the column names, and line 6 and following lines contain the actual data.

# 9. Data Manipulations

#### 9.1 Formulae

The principal equations used to compute wind components and fluxes from the Twin Otter data are given in MacPherson (1990b, 1992, 1996).

## 9.1.1 Derivation Techniques and Algorithms

See MacPherson (1990b, 1992, 1996) and MacPherson and Bastian (1997).

## 9.2 Data Processing Sequence

## 9.2.1 Processing Steps

- AFM-04 processed the data and sent them to BORIS.
- BORIS staff received the data, made necessary conversions to standard units, and loaded the data into the data base.
- BORIS staff documented the data set and compiled basic statistics about the data.

See MacPherson (1988, 1990a, 1990b, 1996) and MacPherson and Bastian (1997) for more detailed information about the processing that AFM-04 did to its data before submitting the data to BORIS.

#### 9.2.2 Processing Changes

There are quite a number of selectable options in the playback program for the Twin Otter data. These include the option to use the alternative (backup) wind computations in case of a problem with the Litton 90/100 IRS.

#### 9.3 Calculations

## 9.3.1 Special Corrections/Adjustments

- Calculation of wind components is described in MacPherson (1981, 1990b, 1996) and MacPherson and Bastian (1997). The air velocity relative to the aircraft is measured by the true air speed (TAS) and noseboom angles of attack and sideslip. The TAS vector is then resolved into Earth axes (north, east, and vertical components). Subtracted from these are the aircraft inertial velocity components measured by a Litton 90/100 IRS, to get the three components of the wind velocity in Earth-fixed axes.
- An alternative, or backup, wind system is employed on the Twin Otter in case the Litton 90 is unserviceable (rare). For this system, known as the NAE/DOP winds, the aircraft inertial velocity relative to Earth is measured in aircraft axes by a system incorporating complementary filtering in real time on the aircraft microprocessor. A system of accelerometers and rate gyros provides the high- frequency components to this filter; the Decca 3-axis Doppler radar provides the low-frequency components. The resulting calculated velocity components in A/C axes are subtracted from the TAS components to get the three components of wind in A/C axes. These are then resolved into Earth axes using the pitch, roll, attitude, and aircraft heading.
- For each flight, the ground speed for all runs is averaged. The high-pass filtered breakpoint is then selected as the average ground speed divided by 5,000 m. This gives a breakpoint of about 0.012 Hz for high-pass filtered flux estimates.
- Three sets of fluxes were derived, one using 'raw' data, one using linearly detrended time histories, and one using high-pass filtered data. All are included in the archive, as well as correlation coefficients and RMS values of parameters contributing to the flux estimates.

### 9.3.2 Calculated Variables

There was no direct measurement of net radiation made on the Twin Otter in BOREAS. Rather, it was calculated at each interval using incident and reflected solar radiation (RADUP and RADOWN), with longwave contributions derived from PRT-5 surface temperature (Ts in Kelvin) and air temperature (Ta in Kelvin) in the following equation:

 $NETRAD = RADUP - RADOWN + [1.20*s*Ta^4 - 171.0] - [0.98*s*Ts^4]$ 

where the last two terms represent the incident and reflected longwave components, using the Stephan-Boltzmann Constant s = 5.6924\*10-8 and a surface emissivity of 0.98. This computed value of net radiation has agreed quite well with tower measurements.

### 9.4 Graphs and Plots

None.

## 10. Errors

#### 10.1 Sources of Error

Errors can result from a number of different sources. The flux measurements are subject to possible errors relating to the measurements from the IRS.

A problem was detected with the ESRI  $CO_2$  analyzer. Possible reasons for this problem are listed in MacPherson (1996). As a result of this problem with the ESRI, data from the LI-COR were reported for the  $CO_2$  and  $H_2O$  fluxes.

## 10.2 Quality Assessment

## 10.2.1 Data Validation by Source

Great care has been taken in the collection and analysis of the Twin Otter data. The wind measuring system is continually monitored for accuracy using techniques such as wind boxes, control input cases, and intercomparisons with other aircraft (Dobosy et al., 1997). Cospectral plots have been used to check the flux contributions at all wavelengths to ensure that they were not contaminated by inadequate compensation for aircraft motion.

Aircraft data were compared at various BOREAS workshops. This led to the decision to include all three sets of fluxes (i.e., from raw, detrended, and HP-filtered time histories) in the data base.

## 10.2.2 Confidence Level/Accuracy Judgment

See Section 10.2.1.

## **10.2.3 Measurement Error for Parameters**

Not available at this revision.

## 10.2.4 Additional Quality Assessments

See Dobosy et al. (1997) for a comparison of fluxes from various aircraft. AFM-04 submitted the following comparison table based on 1996 data.

# COMPARISON BETWEEN TWIN OTTER AND FLUX TOWERS BOREAS 1996

a) Old Aspen - SSA

Date 1996	Flight	Time #1 [GMT]	# runs	Alt #5	Temp [degC]	H [W/m <sup>2</sup> ]	LE #3 [W/m <sup>2</sup> ]	CO <sub>2</sub> Flux #4 [mg/m <sup>2</sup> /s]
July 09	59	2130 2200 2120-2148	6	42	20.92 20.80 20.34	141 85 104	230 252 268 301	-0.61 -0.59 -0.71 -0.89
July 11	61	1730 1703-1730	6	36	21.60 20.59	100 75	338 306 350	-0.81 -0.78 -0.88
July 19	66	1730 1700-1720	4	46	17.86 17.40	204 138	285 266 280	-0.79 -0.80 -0.95
July 26	70	2100 2038-2103	6	32	18.95 17.95	157 84	171 214 260	-0.61 -0.81 -0.95
July 29	73	2030 2001-2025	6	34	23.23 22.19	7 10	93 154 186	-0.15 -0.36 -0.40

#1 - Lines with single time are for tower; lines with time range are for aircraft For Aspen tower, time is for the end of the half hour period.

b) Old Black Spruce - SSA

   Date   1996	Flight	Time #1 [GMT]	# runs	Alt #5	Net Rad [W/m <sup>2</sup> ]	H [W/m <sup>2</sup> ]	LE #3 [W /m <sup>2</sup> ]	CO <sub>2</sub> Flux #4 [mg/m <sup>2</sup> /s]	U* [m/s]
July 10	60	1722 1702-1730	5	43	545 613	349 183	134 173 179	-0.25 -0.22 -0.44	0.87 0.78
July 11	61	1900 1830-1902	6	38	727 583	475 168	336 180 179	-0.29 -0.19 -0.39	0.61 0.62
July 20	67	1100 1044-1047	1	35	-33 -69	-4 -6	3 2 2	+0.04 +0.06 +0.06	0.07 0.00
July 29	72	1630 1558-1626	5	35	483 515	227 134	120 174 199	-0.37 -0.34 -0.53	0.30 0.33

<sup>#1</sup> For tower, time is for end time of 1/2-hour period #3, #4 Left From LI-COR data, right - ESRI #5 From radar altimeter, generally above canopy

c) Old Jackpine - NSA

Date   1996	Flight	Time #1 [GMT]	# runs	Alt	Temp #8 [degC]	Wind [degT /mps]	H [W /m <sup>2</sup> ]	LE #3 [W/m <sup>2</sup> ]	CO <sub>2</sub> Flux #4 [mg /m <sup>2</sup> /s]	U* [m/s]
July 31	76	1700 1715-1732	8	29	25.25	287/5.4 210/4.2	287 236	46 99 81	-0.19 -0.09 -0.40	0.93 0.71
Aug 02	79	1707-1727	8	32	26.03	287/7.2 227/5.6	364 197	95 90 109	-0.105 -0.07 -0.31	1.49 0.89
Aug 05	81	1558-1611 1811-1823	6	32 31	21.62 23.11	201/4.0 203/4.2	141 67	144 145 99 99	-0.13 -0.37 -0.11 -0.21	0.53 0.67

<sup>#1</sup> For tower, time is for start of 1/2-hour period

<sup>#7</sup> Only runs used within tower half-hour

<sup>#3, #4</sup> Left From LI-COR data, right - ESRI

<sup>#5</sup> From radar altimeter, generally above canopy

<sup>#7</sup> Only runs used within tower half-hour

<sup>#8</sup> Tower temperature at 30 m

d) Old Black Spruce - NSA

Date 1996	Flight	Time #1 [GMT]	# runs	Alt	Temp	Wind [degT /mps]	H [W/m <sup>2</sup> ]	LE #3 [W/m <sup>2</sup> ]	CO <sub>2</sub> Flux #4 [mg/m <sup>2</sup> /s]	U* [m/s]
July 30	75	2030 2017-204 8	6	33	27.06 27.25	214/2.9 220/2.4	370 176	113 167 173	-0.017 -0.12 -0.31	0.29 0.42
July 31	76	1700 1650-171 3	5	34	24.89 24.97	216/4.3 215/3.8	501 194	206 137 143	-0.22 -0.18 -0.40	0.80 0.63
Aug 02	79	1700 1642-170 4	5	33	25.49 25.63	227/6.4 237/5.6	294 145	176 184 232	-0.26 -0.19 -0.35	0.91 0.83
Aug 03	80	1800 1830 1806-183 4	6	32	26.35 26.76 26.66	123/3.7 135/2.8 116/3.2	420 335 203	82 195 158 171	-0.21 -0.23 -0.18 -0.39	0.56 0.61 0.54
Aug 07	82	1500 1530 1456-151 4 1532-154 9	4 4	31 34	12.16 12.66 12.88 13.48	285/3.7 283/4.1 294/4.9 289/4.3	94 84 47 86	142 103 143 181 191 209	-0.27 -0.24 -0.29 -0.50 -0.36 -0.52	0.63 0.58 0.58 0.63
Aug 08	83	1700 1645-171 4	6	32	10.73 11.04	002/2.9 018/4.3	233 182	75 136 138	-0.30 -0.50 -0.76	0.51 0.63

#1 For tower, time is for mid time of 1/2-hour period

## 10.2.5 Data Verification by Data Center

Data were examined for general consistency and clarity.

## 11. Notes

### 11.1 Limitations of the Data

None given.

## 11.2 Known Problems with the Data

Despite careful study by Agriculture Canada technicians and some modifications to the ESRI instrument, data from 1996 suggest that the problems with the ESRI analyzer persisted.

# 11.3 Usage Guidance

Note that although there are fewer than 100 records in any data file, there are over 170 columns of data. Most spreadsheet software should be able to handle up to 256 columns of data.

## 11.4 Other Relevant Information

None.

# 12. Application of the Data Set

These data can be used to obtain study area and regional scale estimates of the various fluxes.

## 13. Future Modifications and Plans

None given.

## 14. Software

## 14.1 Software Description

The program used to generate the flux estimates for 1994 and output numerous summary files was called ARCPOK94, which was run on a MicroVAX Alpha computer used in the field and in the lab.

The program used to generate the flux estimates for 1996 and output numerous summary files for archive purposes was called ARCPOK96\_NEW, which was run on the MicroVAX Alpha computer used in the field and at the Flight Research Laboratory (FRL) in Ottawa. The principal equations used to compute wind components and fluxes from Twin Otter data are given in MacPherson (1996) and MacPherson and Bastian (1997). Contact Ian MacPherson for more information.

#### 14.2 Software Access

None given.

#### 15. Data Access

The Twin Otter aircraft flux data are available from the Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

#### 15.1 Contact Information

For BOREAS data and documentation please contact:

ORNL DAAC User Services Oak Ridge National Laboratory P.O. Box 2008 MS-6407 Oak Ridge, TN 37831-6407

Phone: (423) 241-3952 Fax: (423) 574-4665

E-mail: ornldaac@ornl.gov or ornl@eos.nasa.gov

#### 15.2 Data Center Identification

Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC) for Biogeochemical Dynamics http://www-eosdis.ornl.gov/ [Internet Link].

### 15.3 Procedures for Obtaining Data

Users may obtain data directly through the ORNL DAAC online search and order system [http://www-eosdis.ornl.gov/] and the anonymous FTP site [ftp://www-eosdis.ornl.gov/data/] or by contacting User Services by electronic mail, telephone, fax, letter, or personal visit using the contact information in Section 15.1.

#### 15.4 Data Center Status/Plans

The ORNL DAAC is the primary source for BOREAS field measurement, image, GIS, and hardcopy data products. The BOREAS CD-ROM and data referenced or listed in inventories on the CD-ROM are available from the ORNL DAAC.

# 16. Output Products and Availability

## **16.1 Tape Products**

Not applicable.

### 16.2 Film Products

Not applicable.

#### 16.3 Other Products

These data are available on the BOREAS CD-ROM series.

## 17. References

## 17.1 Platform/Sensor/Instrument/Data Processing Documentation

The Twin Otter Atmospheric Research Aircraft and its instrumentation have been described in the following reports available from the National Research Council of Canada:

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## 17.2 Journal Articles and Study Reports

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Dobosy, R.J., T.L. Crawford, J.I. MacPherson, R.L. Desjardins, R.D. Kelly, S.P. Oncley, and D.H. Lenschow. 1997. Intercomparison among four flux aircraft at BOREAS in 1994. Journal of Geophysical Research 102(D24): 29,101-29,111.

MacPherson, J.I. and A.K. Betts. 1997. Aircraft encounters with strong coherent vortices over the boreal forest. Journal of Geophysical Research 102(D24): 29,231-29,234.

MacPherson, J.I. and R.L. Desjardins. 1991. Airborne Tests of Flux Measurement by the Relaxed Eddy Accumulation Technique. Proceedings of the Seventh Symposium on Meteorological Observations and Instrumentation. American Meteorological Society. New Orleans. January, 1991.

Newcomer, J., D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers, eds. 2000. Collected Data of The Boreal Ecosystem-Atmosphere Study. NASA. CD-ROM.

Ogunjemiyo, S., P.H. Schuepp, J.I. MacPherson, and R.L. Desjardins. 1997. Analysis of flux maps versus surface characteristics from Twin Otter grid flights in BOREAS 1994. Journal of Geophysical Research 102(D24): 29,135-29,145.

Sellers, P. and F. Hall. 1994. Boreal Ecosystem-Atmosphere Study: Experiment Plan. Version 1994-3.0, NASA BOREAS Report (EXPLAN 94).

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# **17.3 Archive/DBMS Usage Documentation** None.

## 18. Glossary of Terms

None.

# 19. List of Acronyms

- Atmospheric Environment Service AES AFM - Airborne Fluxes and Meteorology

AGL - Above Ground Level

ASCII - American Standard Code for Information Interchange

BOREAS - BOReal Ecosystem-Atmosphere Study

BORIS - BOREAS Information System CD-ROM - Compact Disk-Read-Only Memory DAAC - Distributed Active Archive Center

DAT - Digital Archive Tape EOS - Earth Observing System

EOSDIS - EOS Data and Information System FIFE - First ISLSCP Field Experiment FIS - FIFE Information System

FRL - Flight Research Laboratory
GIS - Geographic Information System
GMT - Greenwich Mean Time

GSFC - Goddard Space Flight Center

HP - high pass

HTML - HyperText Markup Language

IAR - Institute for Aerospace Research

IFC - Intensive Field Campaign
INS - Inertial Navigation System
IRS - Inertial Reference System

ISLSCP - International Satellite Land Surface Climatology Project

MSL - Mean Sea Level

NAE - National Aeronautical Establishment

NASA - National Aeronautics and Space Administration

NCAR - National Center for Atmospheric Re
NRC - National Research Council, Canada
NSA - Northern Study Area
OA - Old Aspen - National Center for Atmospheric Research

OBS - Old Black Spruce OJP - Old Jack Pine

ORNL - Oak Ridge National Laboratory PANP - Prince Albert National Park

- Root Mean Square - Southern Study Area RMS SSA

TAS - True Air Speed

- Uniform Resource Locator URL

- Young Aspen ΥA YJP - Young Jack Pine

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## If using data from the BOREAS CD-ROM series, also reference the data as:

MacPherson, J.I. and R.L. Desjardins, "Atmospheric Boundary Layer Analyses from Canadian Twin Otter Aircraft." In Collected Data of The Boreal Ecosystem-Atmosphere Study. Eds. J. Newcomer, D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers. CD-ROM. NASA, 2000.

### Also, cite the BOREAS CD-ROM set as:

Newcomer, J., D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers, eds. Collected Data of The Boreal Ecosystem-Atmosphere Study. NASA. CD-ROM. NASA, 2000.

#### **20.5 Document Curator**

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#### 13. ABSTRACT (Maximum 200 words)

The BOREAS AFM-4 team used the NRC Twin Otter aircraft in 1994 and 1996 to make measurements in the boundary layer of the fluxes of sensible and latent heat, momentum, ozone, methane, and carbon dioxide, plus supporting meteorological parameters such as temperature, humidity, and wind speed and direction. Aircraft position, heading, and altitude were also recorded, as were several radiometric observations for use in interpretation of the data (greenness index, surface temperature, incoming and reflected radiation). Data were collected at both the NSA and SSA during the three 1994 IFCs and in July and August of 1996. These data are stored in tabular ASCII files.

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